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Takebe et al.

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(54) **INTERMEDIATE STORAGE DEVICE OF ELECTROSTATIC COATING SYSTEM , METHOD FOR CLEANING THE SAME, AND METHOD FOR COATING**

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B08B 9/032 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B08B 9/032*** (2013.01); ***B05B 5/1625*** (2013.01); ***B05B 5/1675*** (2013.01); ***B05B 12/1418*** (2013.01); ***B05B 15/02*** (2013.01); ***B05D 1/007*** (2013.01)

(58) **Field of Classification Search**
CPC B08B 9/032
See application file for complete search history.

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Primary Examiner — Michael Barr
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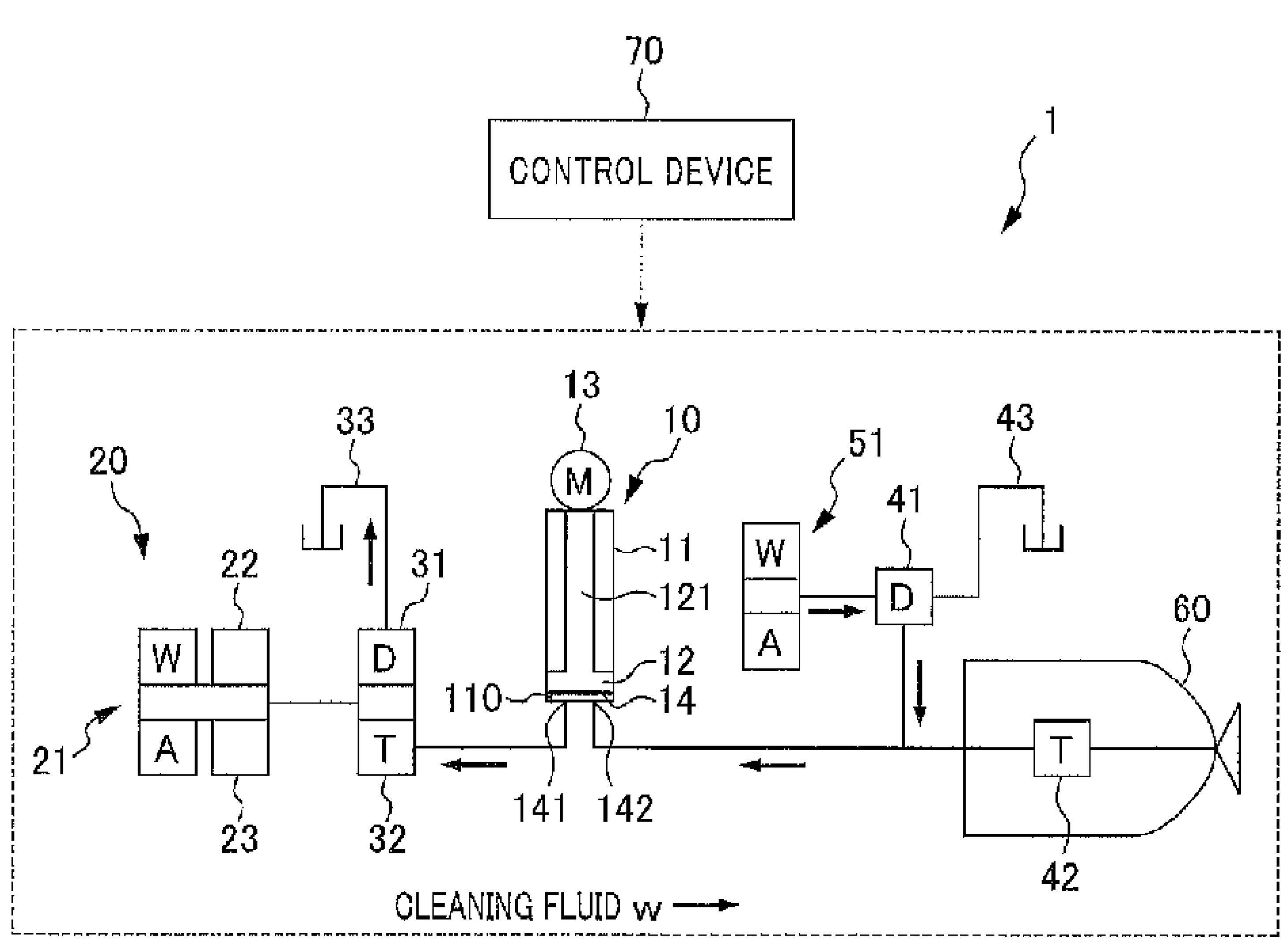
(74) *Attorney, Agent, or Firm* — Rankin, Hill & Clark LLP

(57) **ABSTRACT**

The invention provides an intermediate storage device of an electrostatic coating system that can clean efficiently, a method for cleaning the same, and a method for coating. An intermediate storage device **10** comprises: a first hole **141** which is open to a cylinder chamber **14** and is connected to a paint supply source; a second hole **142** which is open to the cylinder chamber **14** and is connected to a coating gun; and a switch means which switches between a first cleaning which cleans the cylinder chamber **14** by supplying cleaning fluid W from the first hole **141** and discharging from the second hole **142** waste fluid that has undergone cleaning and a second cleaning which cleans the cylinder chamber **14** by supplying cleaning fluid W from the second hole **142** and discharging from the first hole **141** waste fluid that has undergone cleaning.

6 Claims, 12 Drawing Sheets



(51) **Int. Cl.**

B05D 1/00	(2006.01)
B05B 5/16	(2006.01)
B05B 12/14	(2006.01)
B05B 15/02	(2006.01)

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FIG. 1

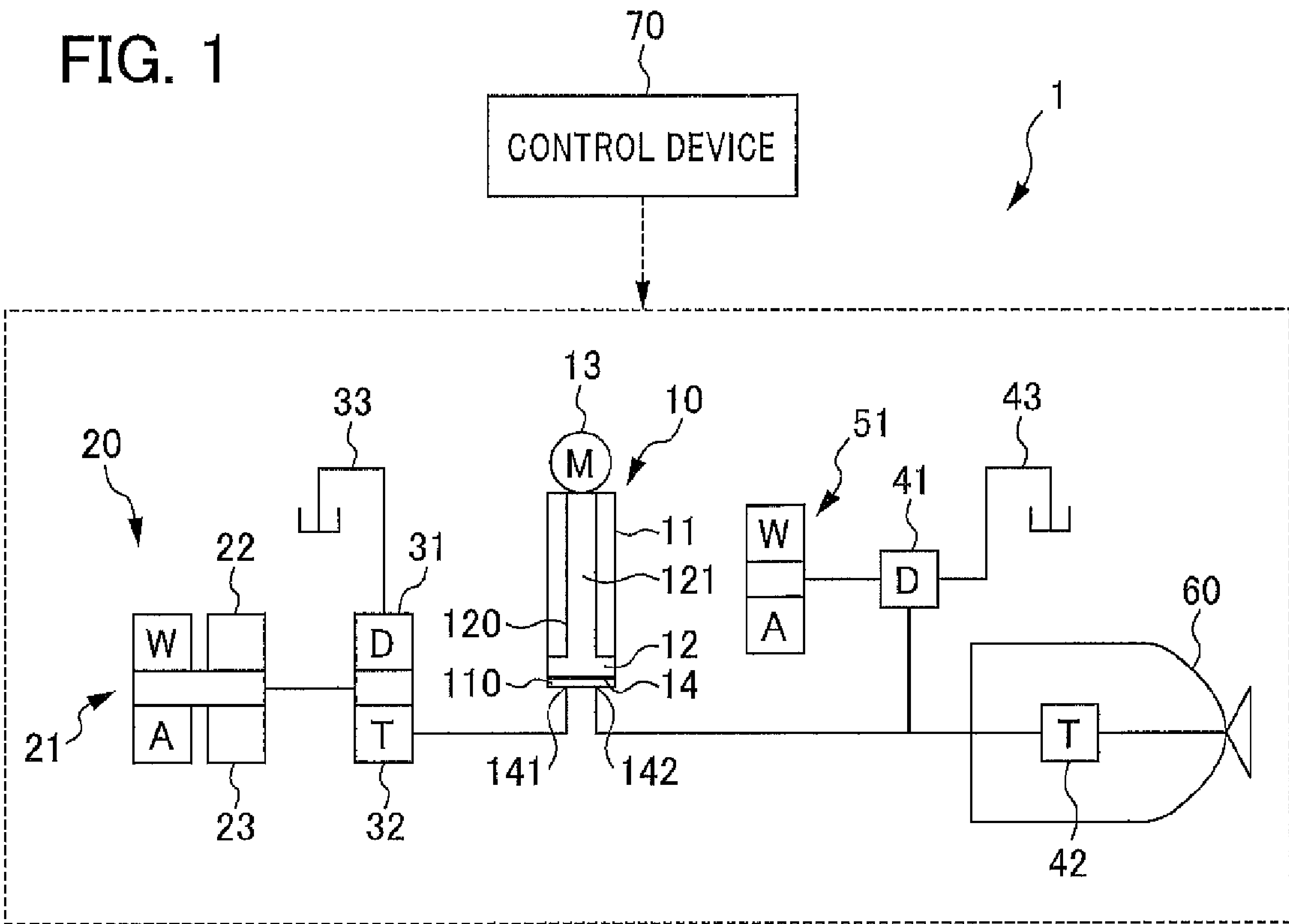

70
CONTROL DEVICE
1
13
M
10
20
33
31
22
W
A
D
T
21
23
32
11
121
120
12
110
14
141
142
51
W
A
41
D
43
60
T
42

FIG. 2

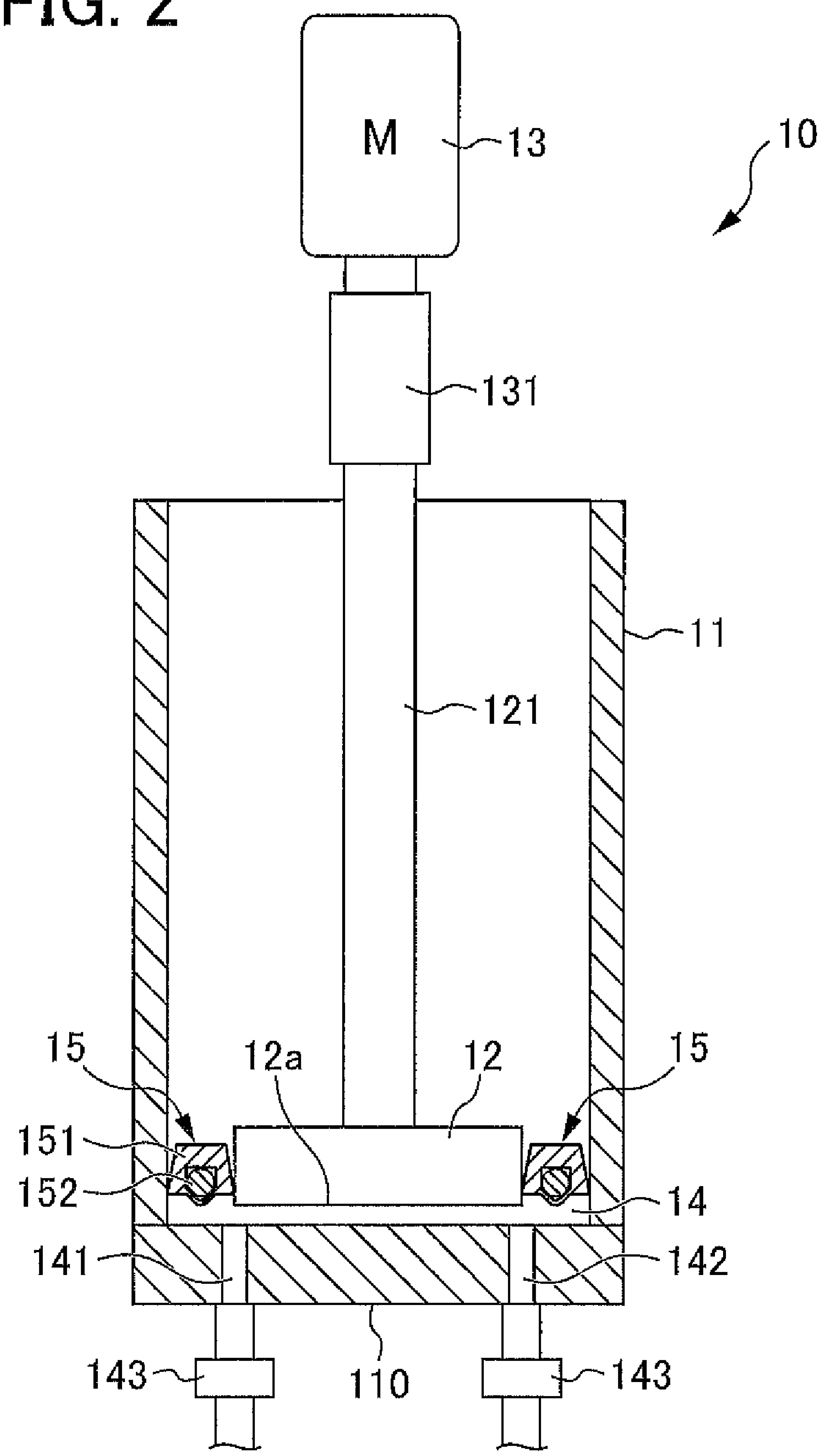


FIG. 3A

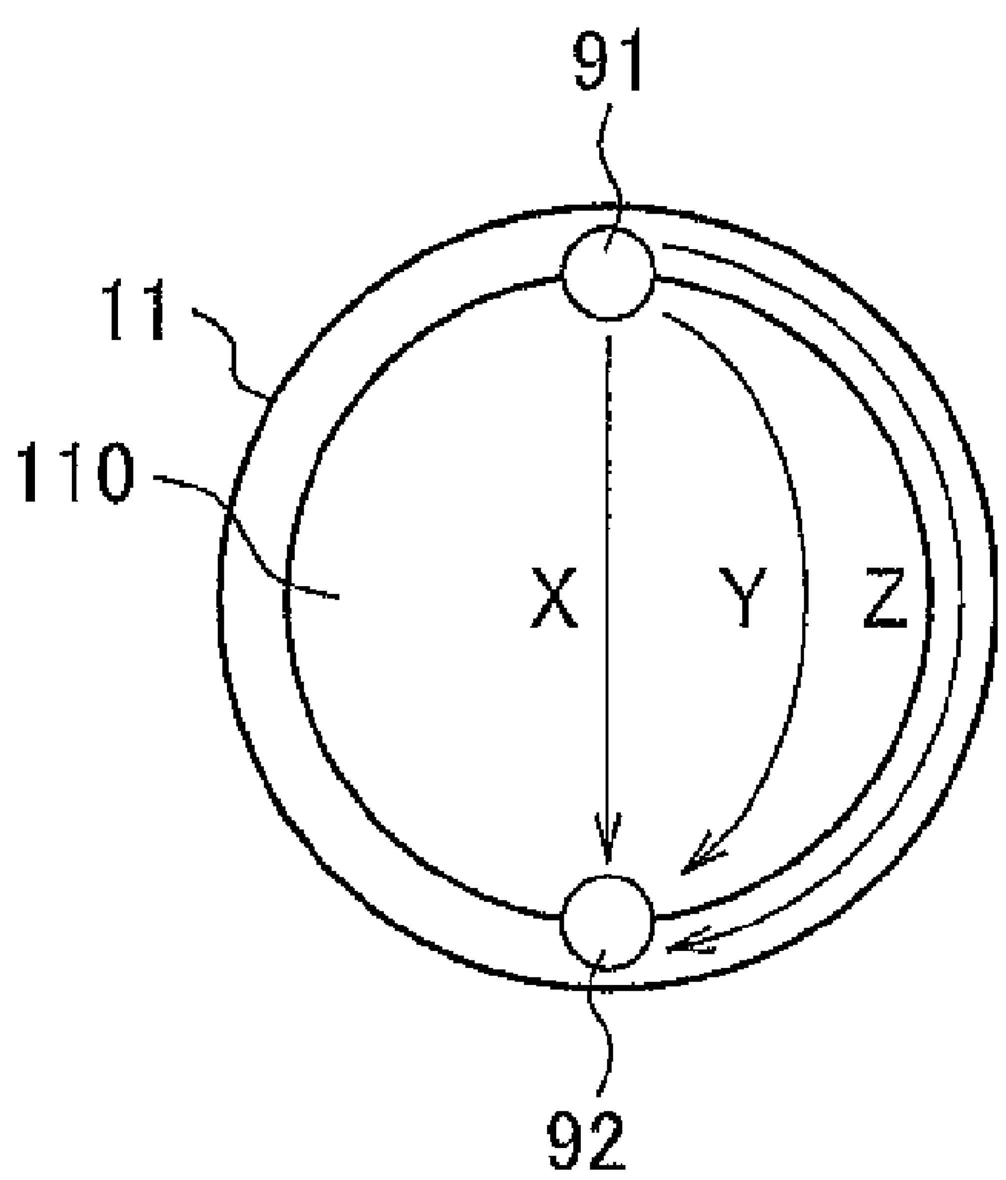


FIG. 3B

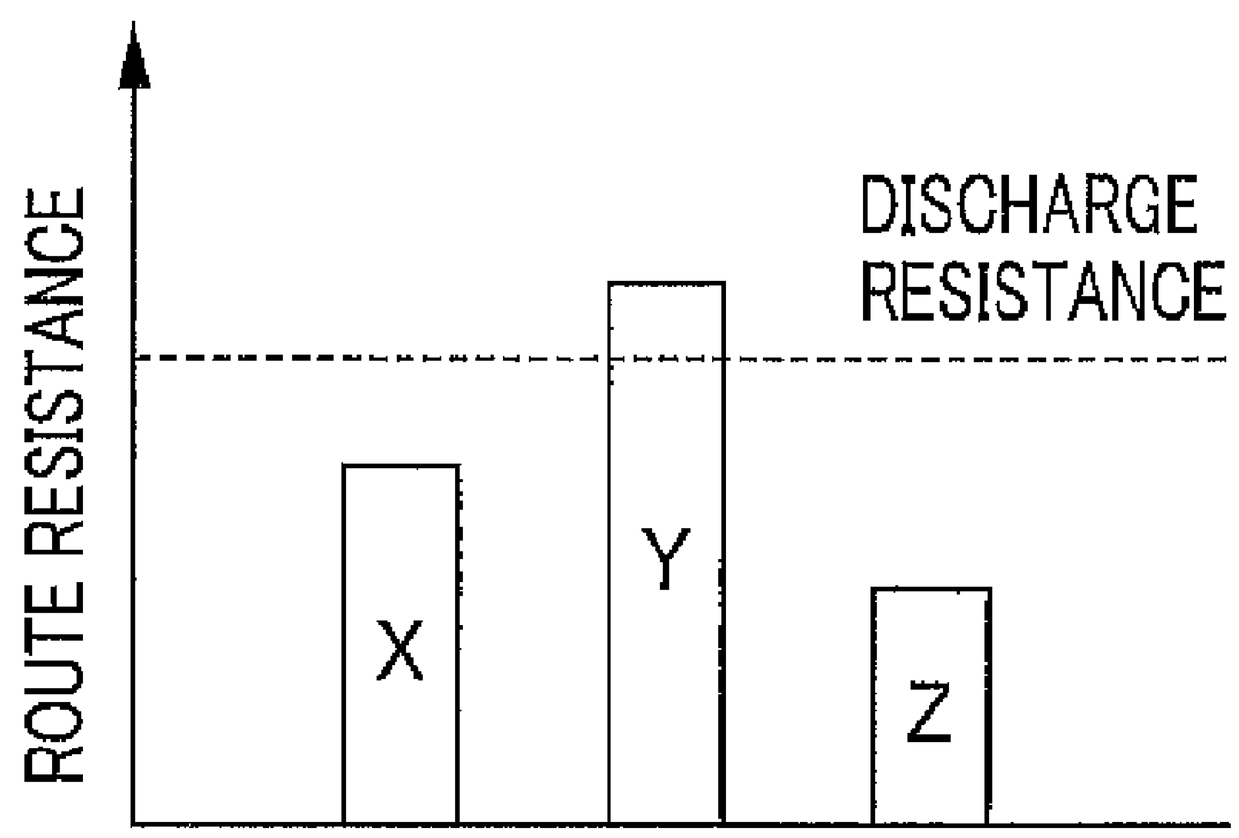


FIG. 3C

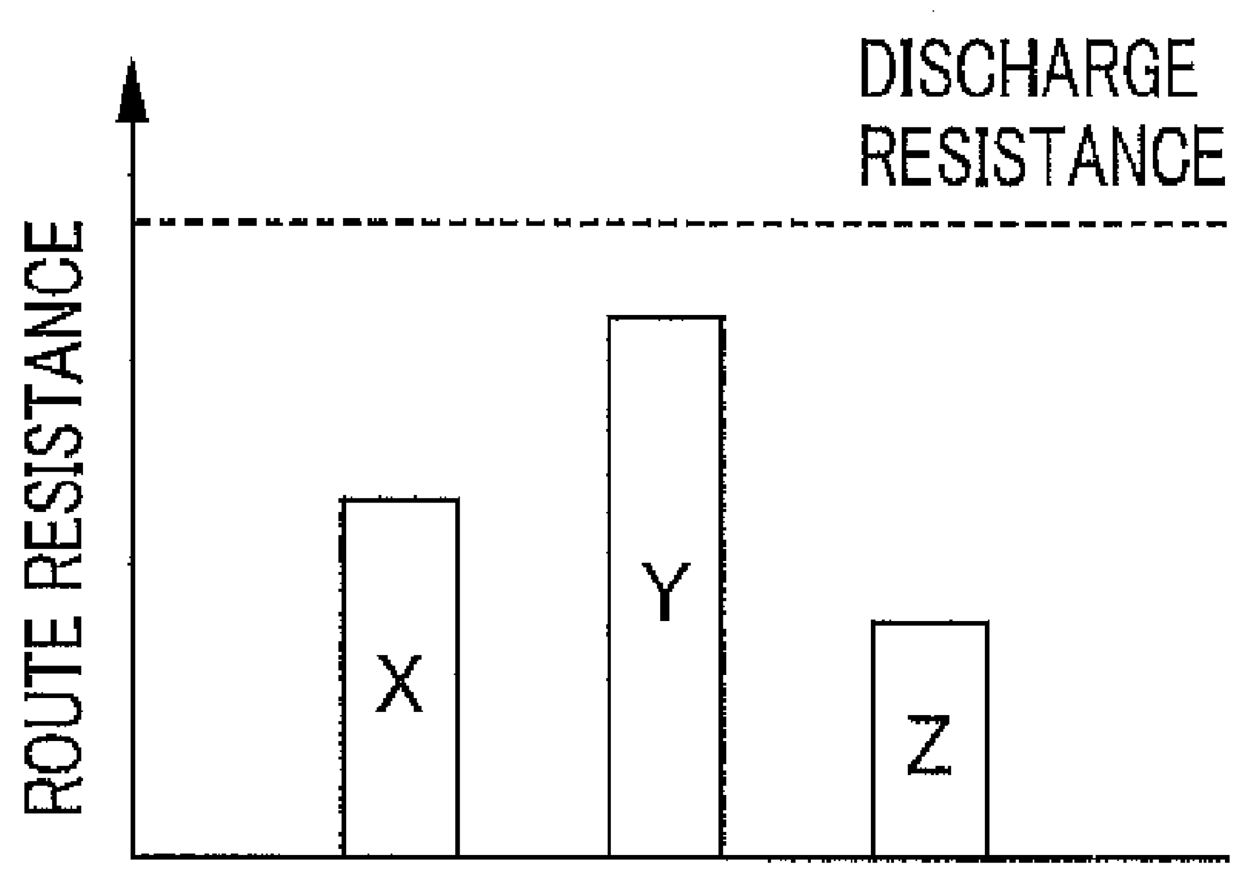
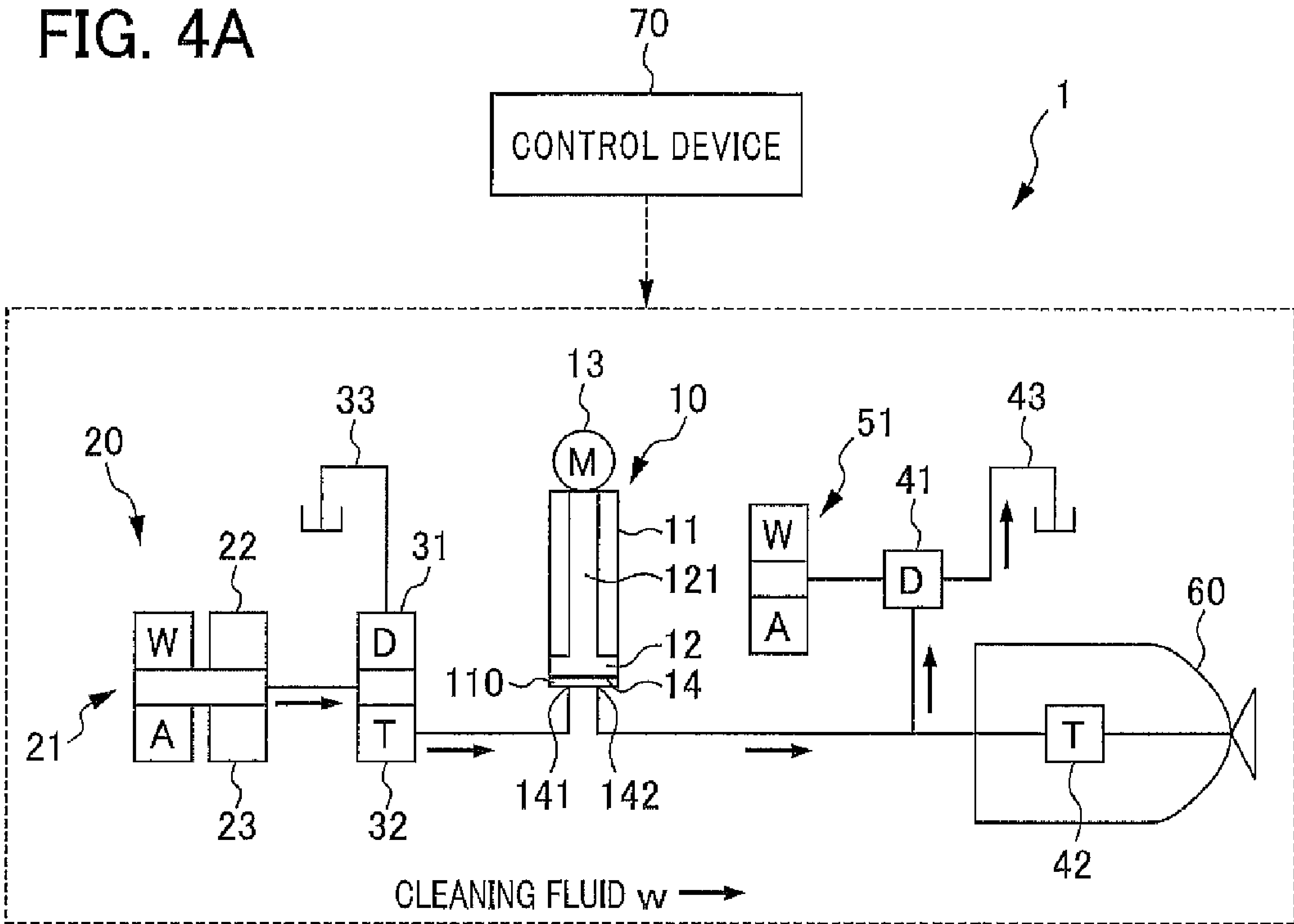
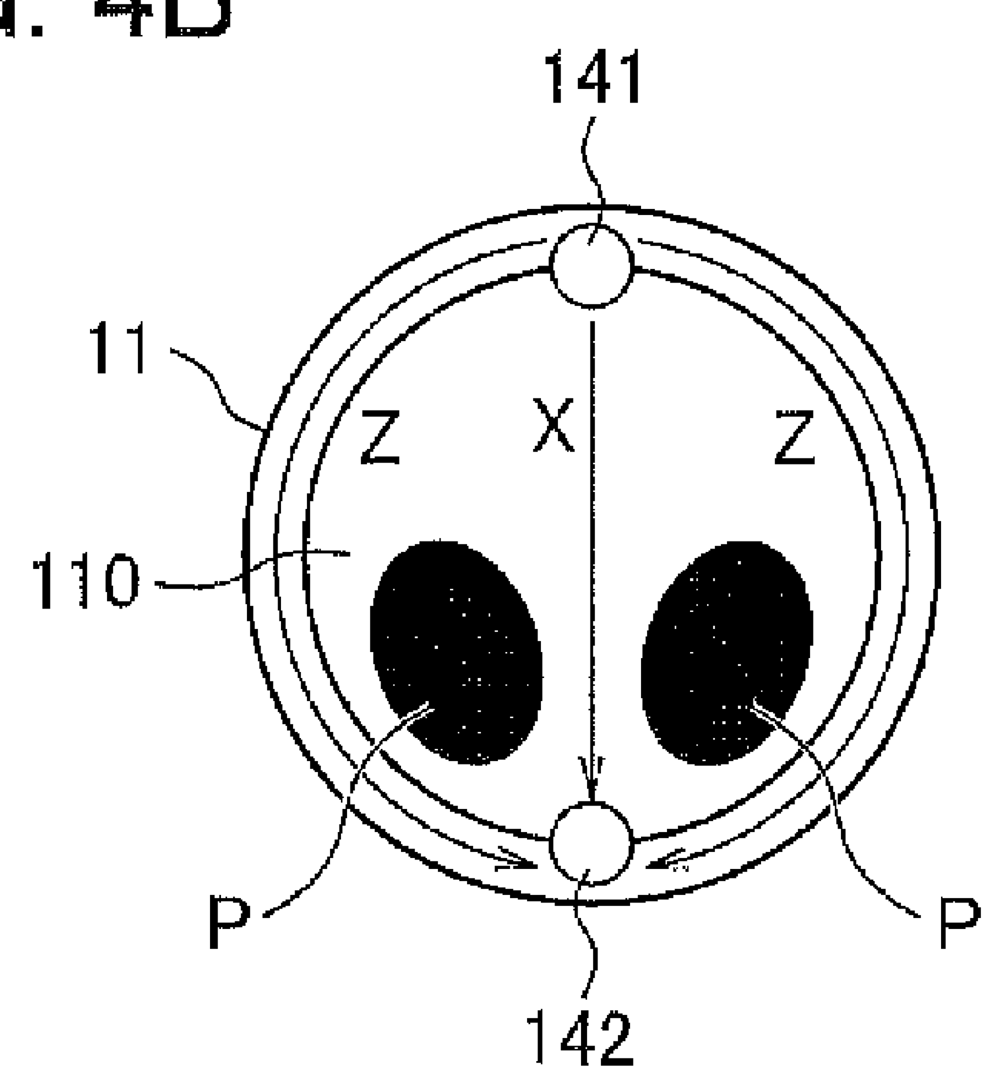


FIG. 4A



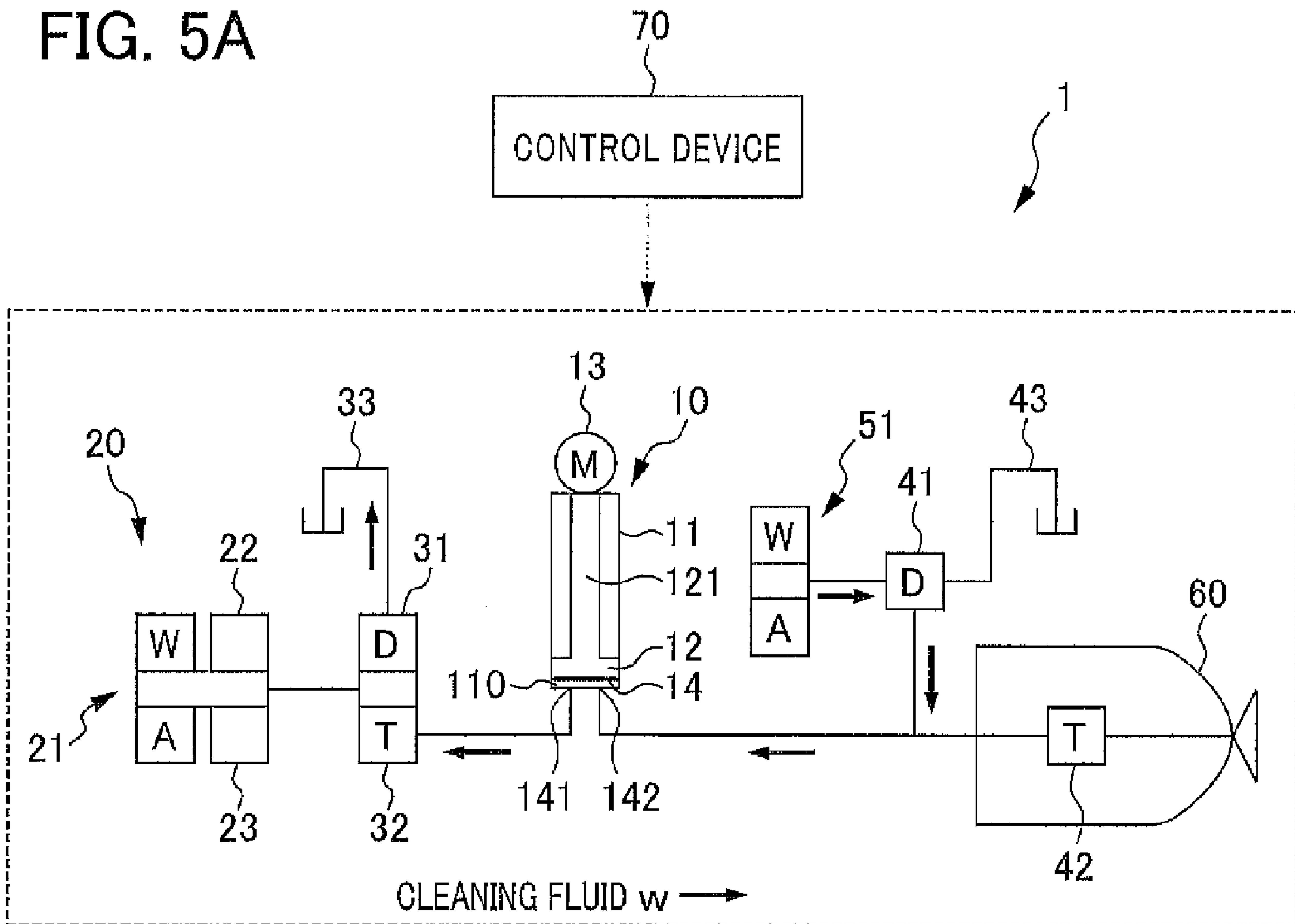
70
CONTROL DEVICE
1
13
10
M
20
33
51
43
41
22
31
11
W
121
D
W
D
60
A
12
110
14
21
A
T
T
141
142
23
32
42
CLEANING FLUID w

FIG. 4B



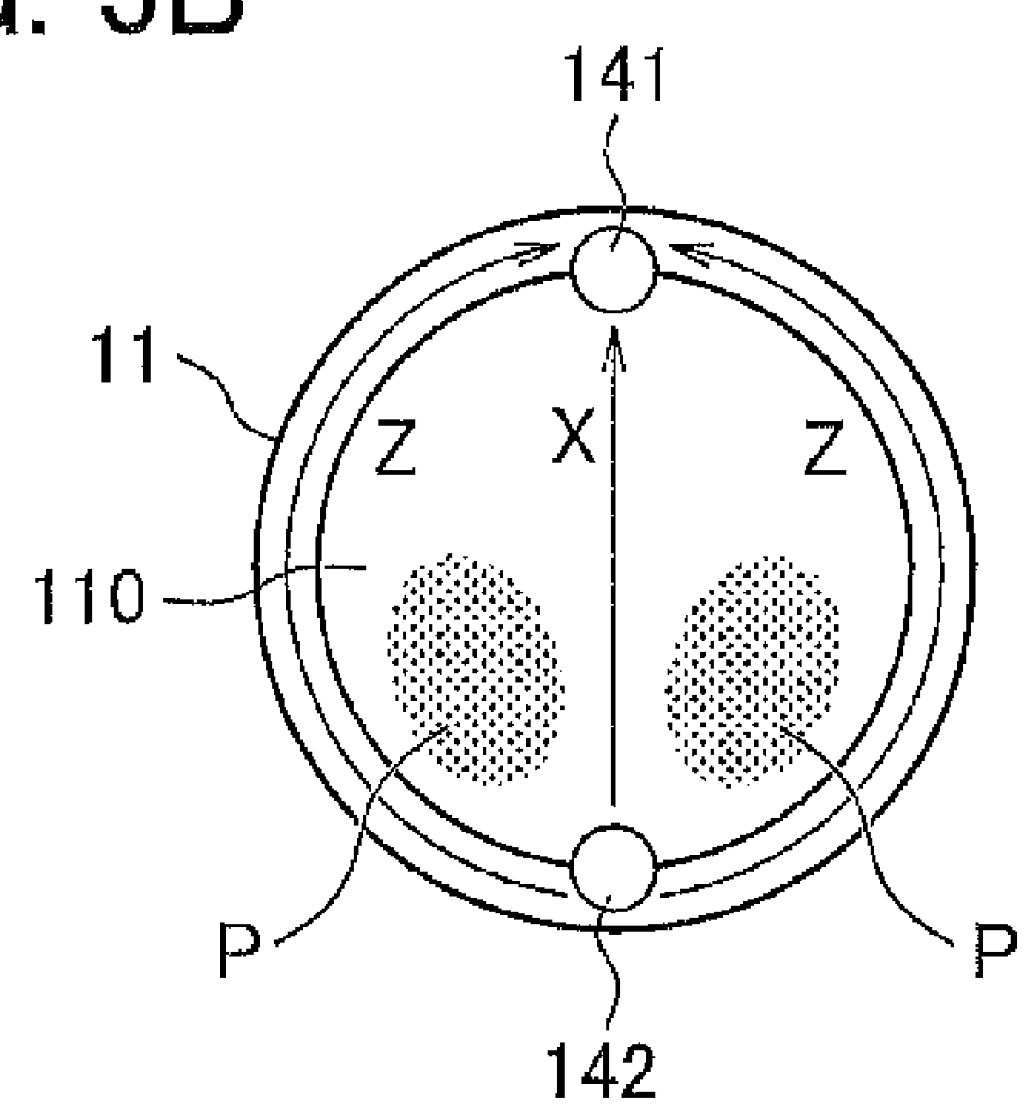
141
11
Z
X
Z
110
P
P
142

FIG. 5A



70
CONTROL DEVICE
1
13
M
10
33
43
51
41
20
22
31
W
D
11
121
12
14
110
W
A
D
60
21
A
T
T
141
142
23
32
42
CLEANING FLUID w

FIG. 5B



141
11
Z
X
Z
110
P
P
142

FIG. 6A

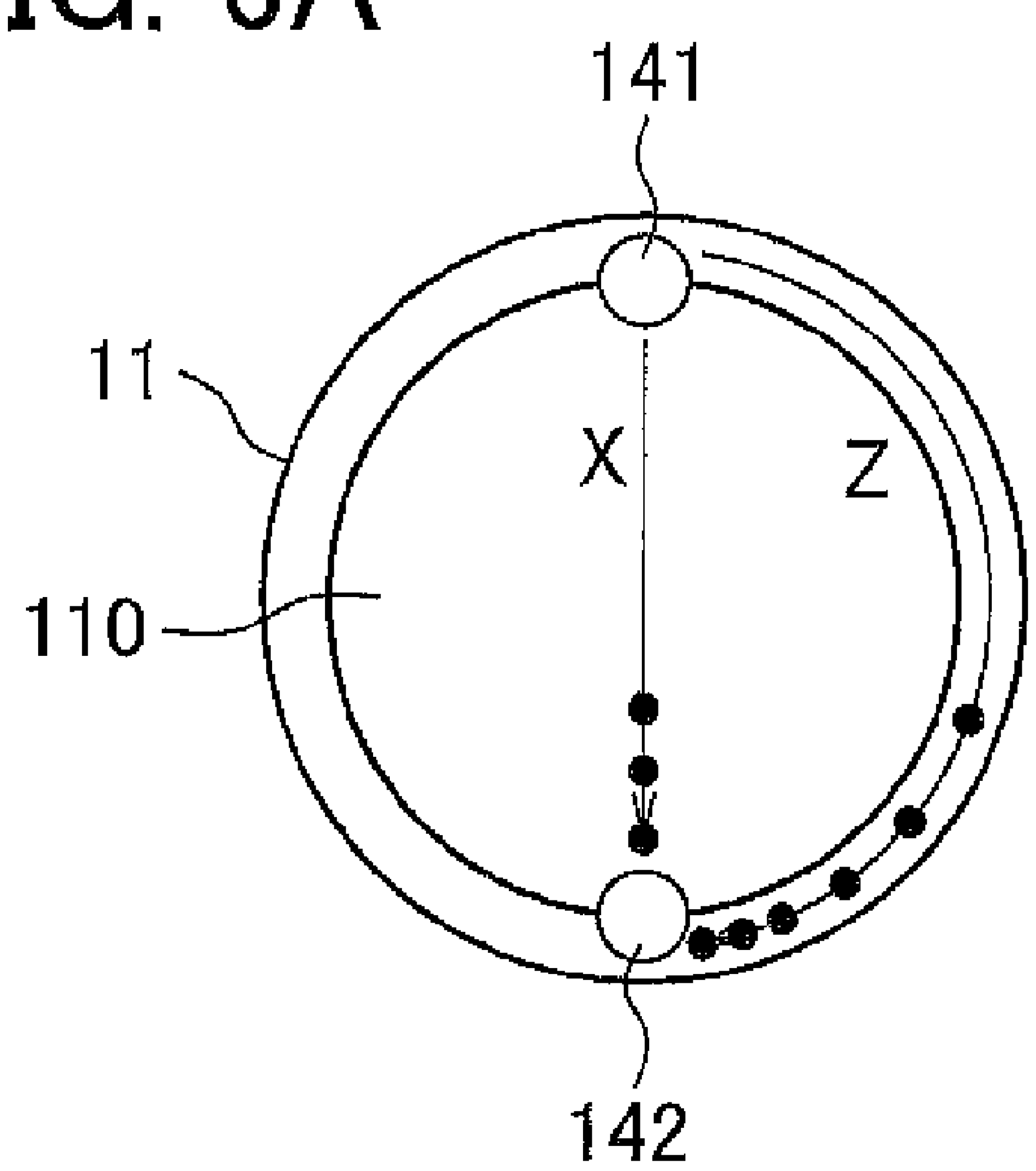


FIG. 6B

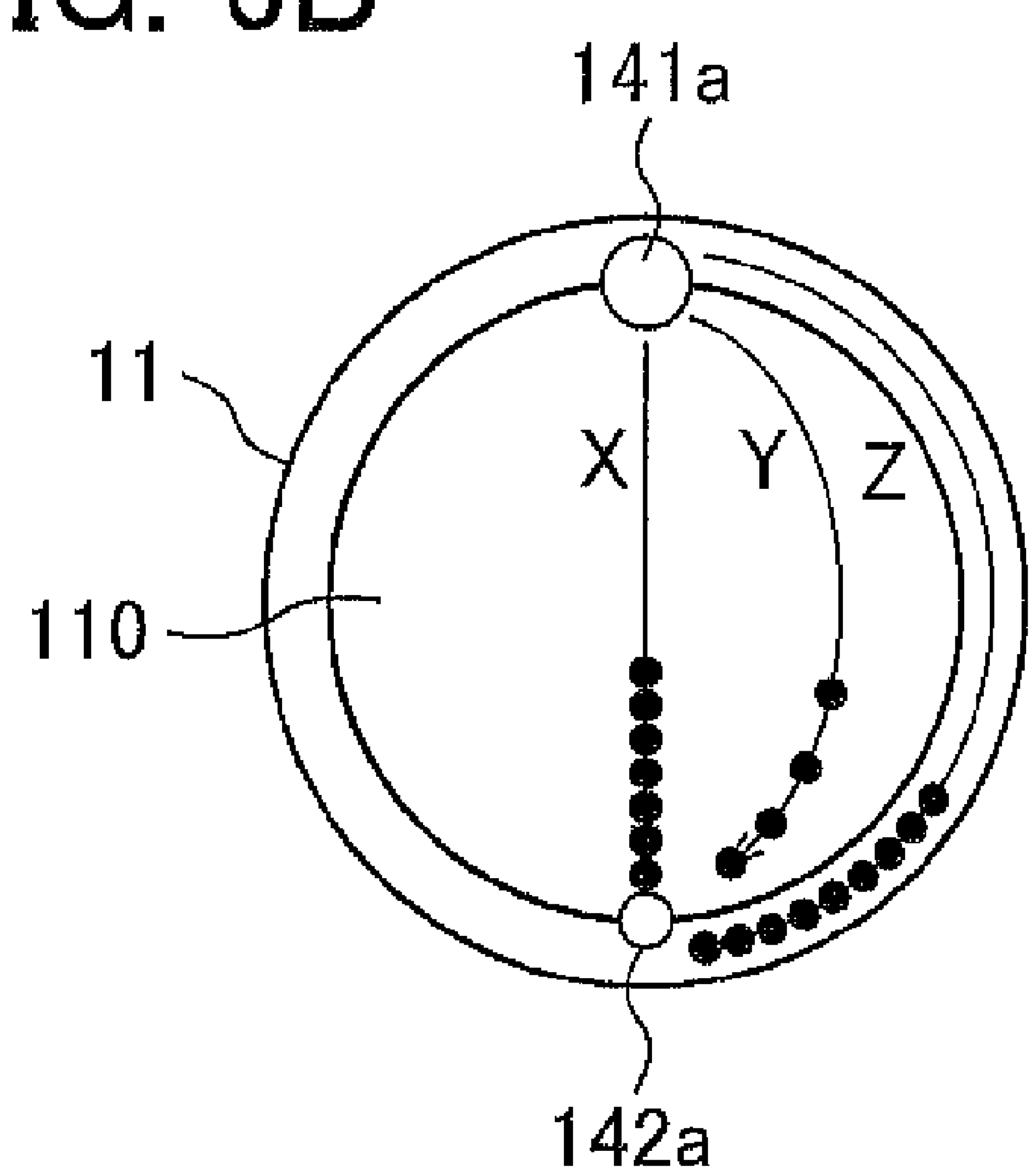
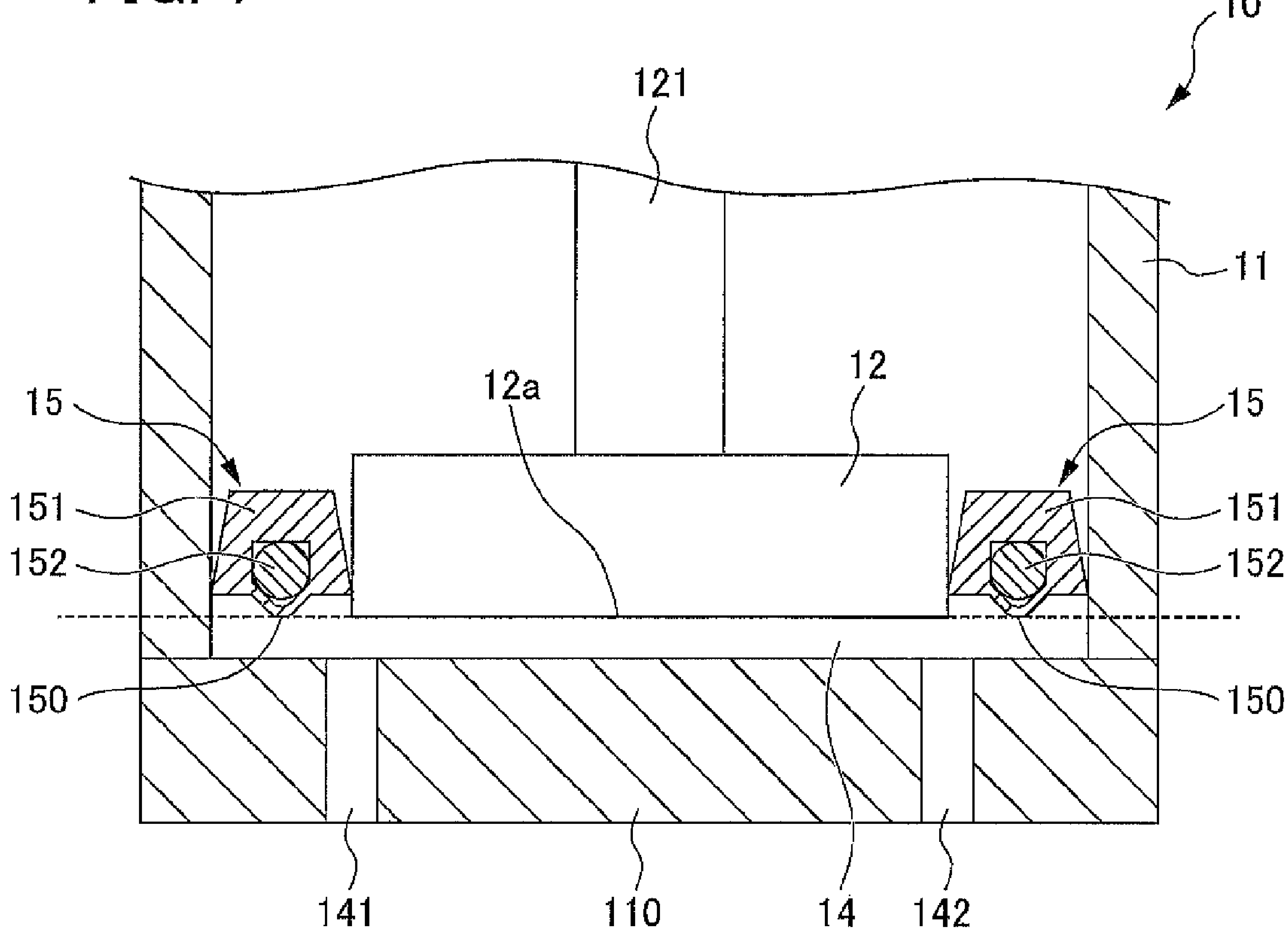


FIG. 7



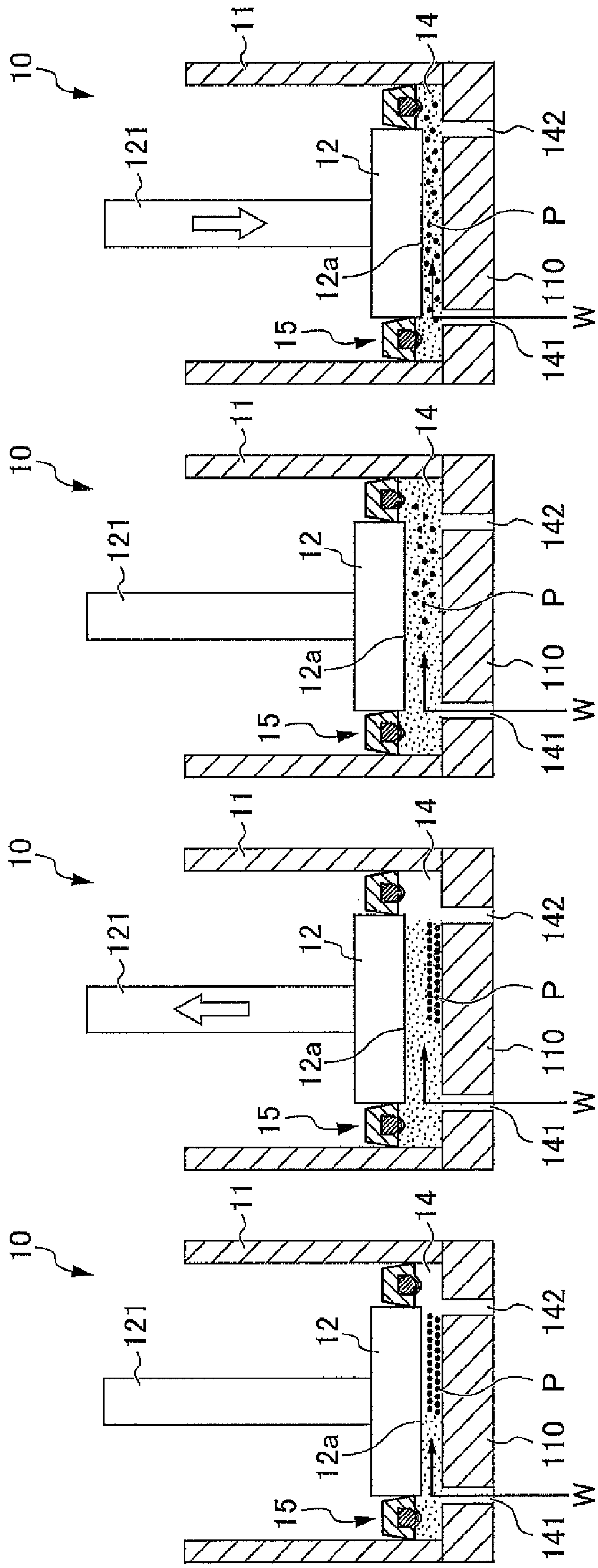


FIG. 8A

FIG. 8B

FIG. 8C

FIG. 8D

FIG. 9

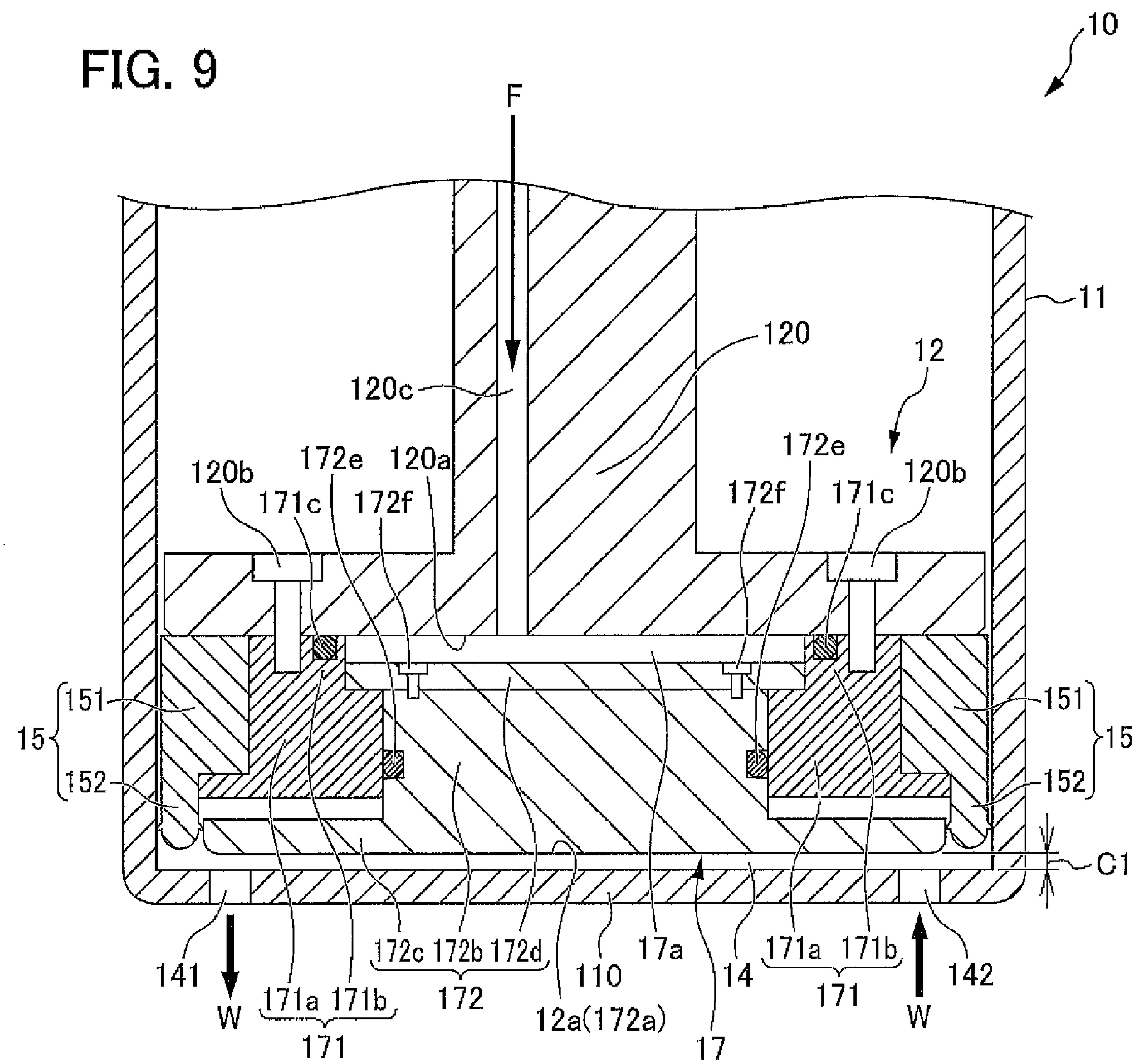

10
F
11
120
12
120c
172e
120a
120b
171c
172f
172e
172f
171c
120b
151
15
152
151
15
152
C1
141
W
171a 171b
171
172c 172b 172d
172
110
12a(172a)
17a
17
14
171a 171b
171
142
W

FIG. 10

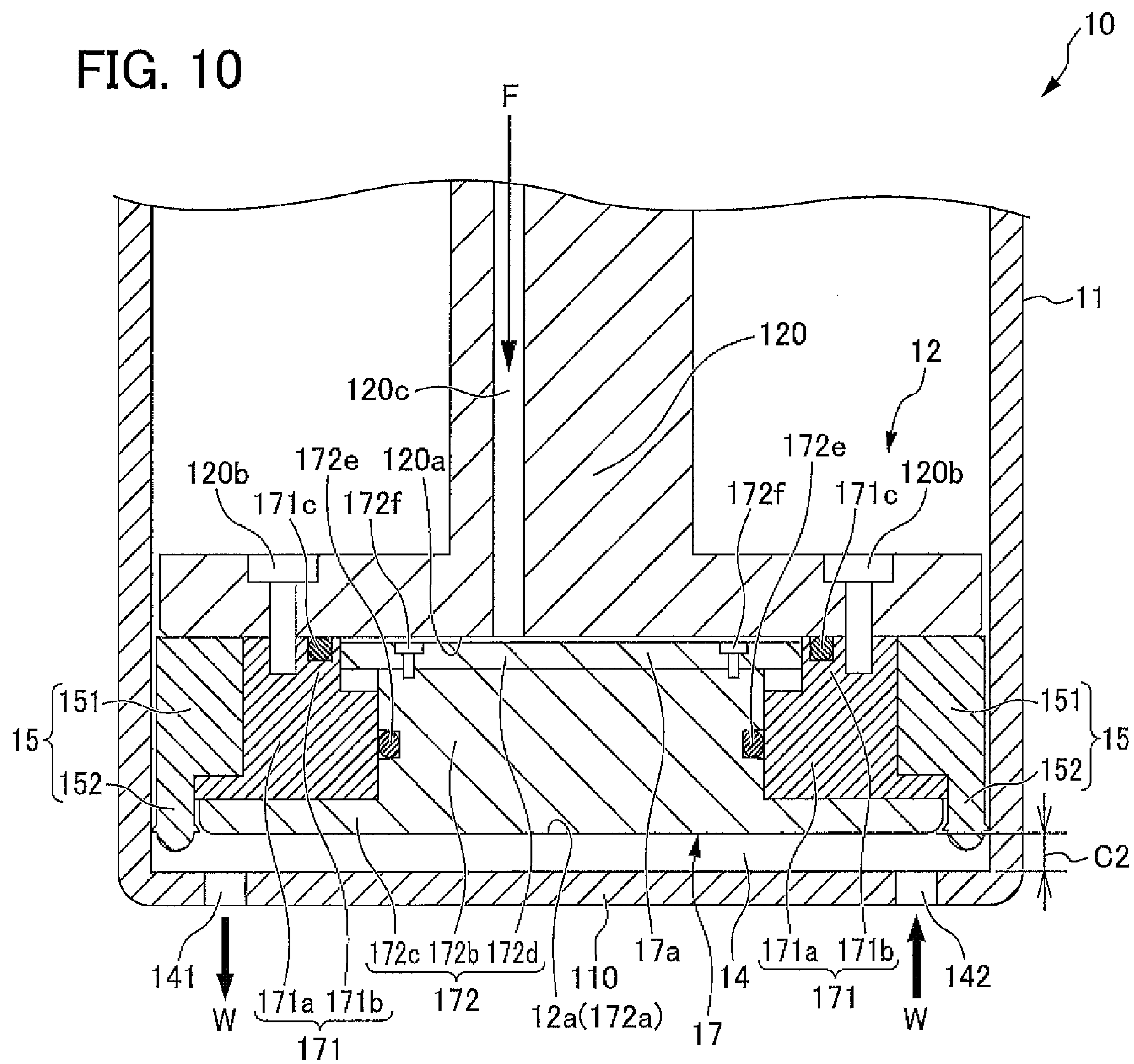

10
F
11
120
12
120c
172e
120b
172e
120a
120b
171c
172f
172f
171c
151
151
15
15
152
152
C2
141
W
171a 171b
171
172c 172b 172d
172
110
12a(172a)
17a
17
14
171a 171b
171
142
W

FIG. 11

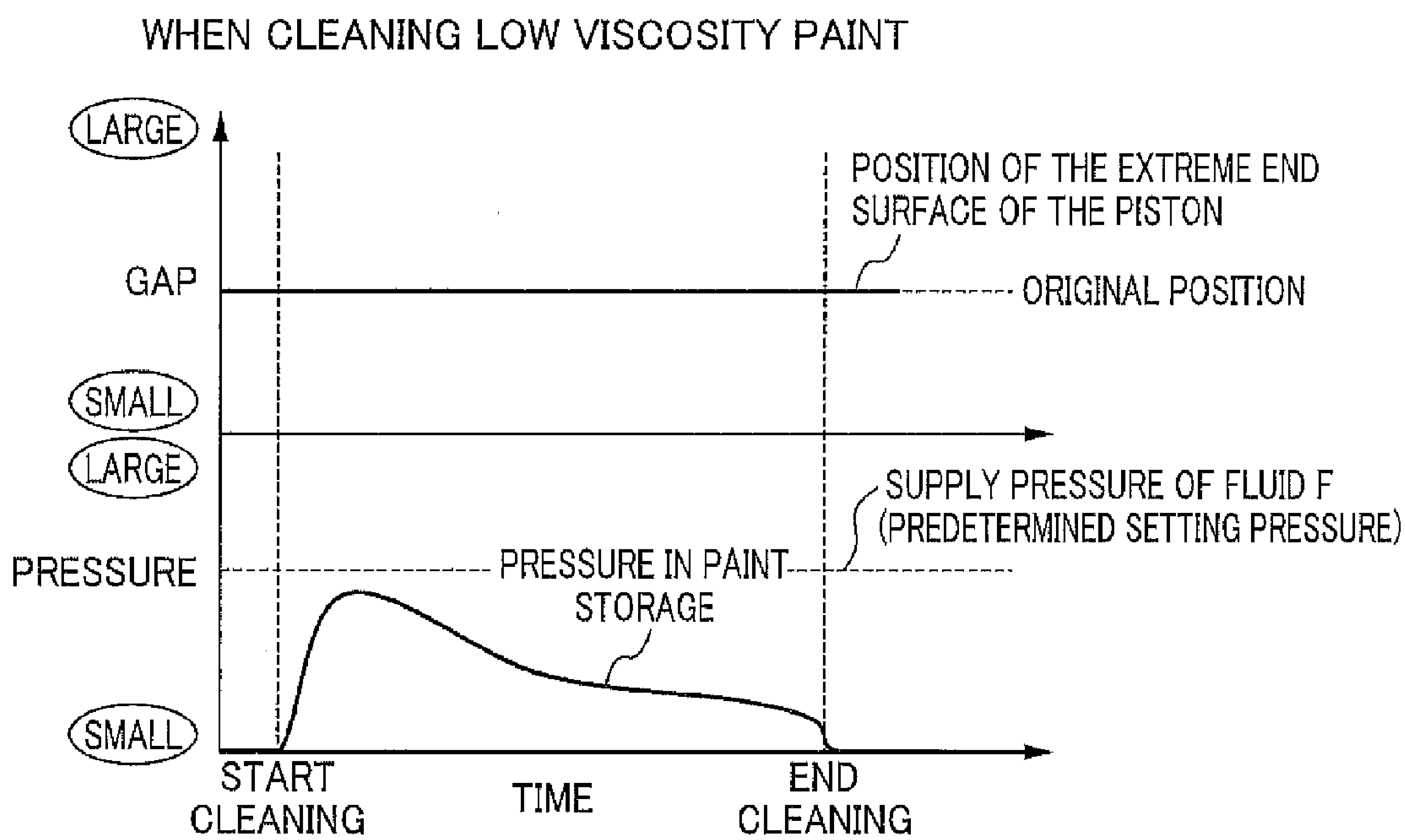

WHEN CLEANING LOW VISCOSITY PAINT
LARGE
GAP
SMALL
POSITION OF THE EXTREME END SURFACE OF THE PISTON
ORIGINAL POSITION
LARGE
PRESSURE
SMALL
SUPPLY PRESSURE OF FLUID F (PREDETERMINED SETTING PRESSURE)
PRESSURE IN PAINT STORAGE
START CLEANING
TIME
END CLEANING

FIG. 12

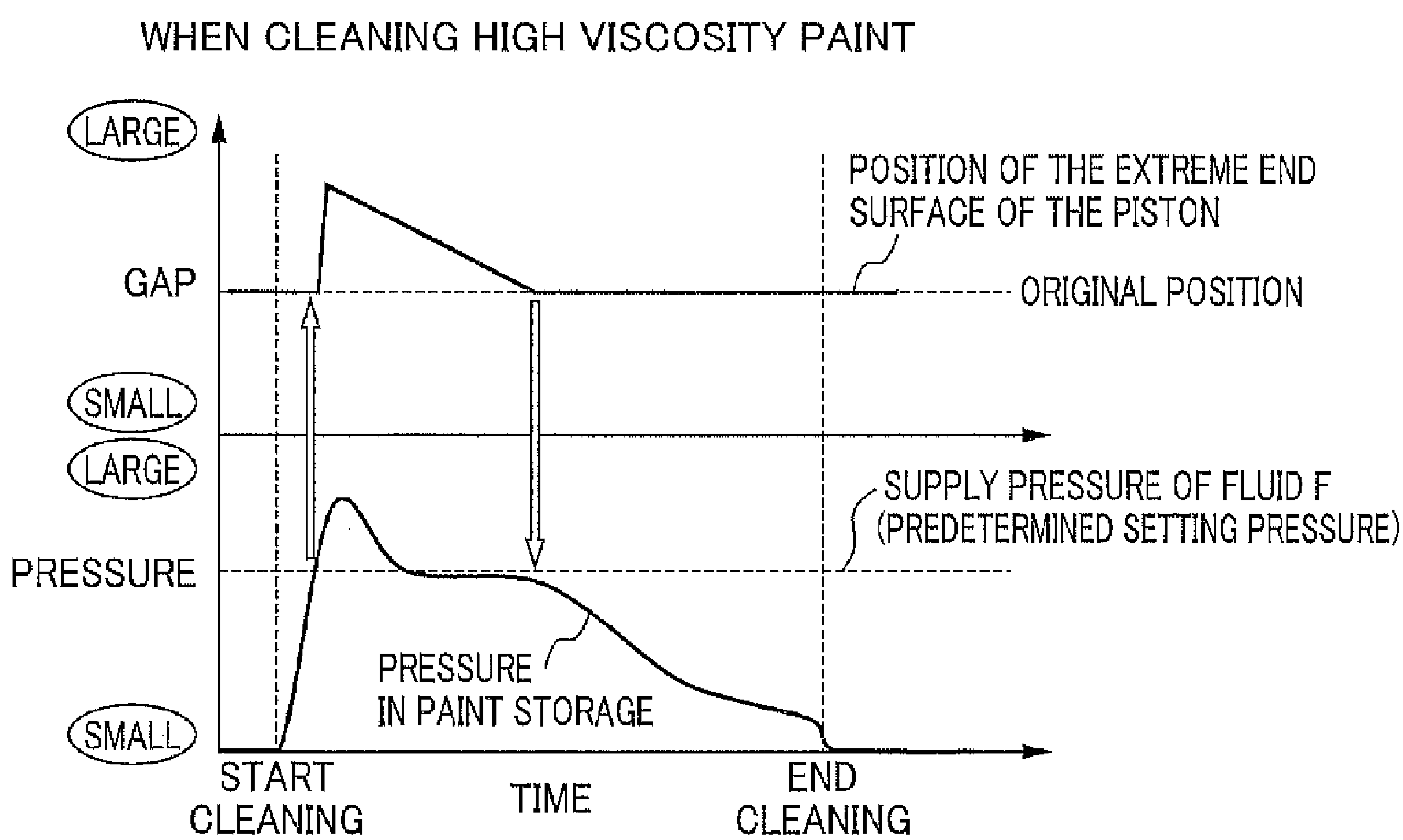
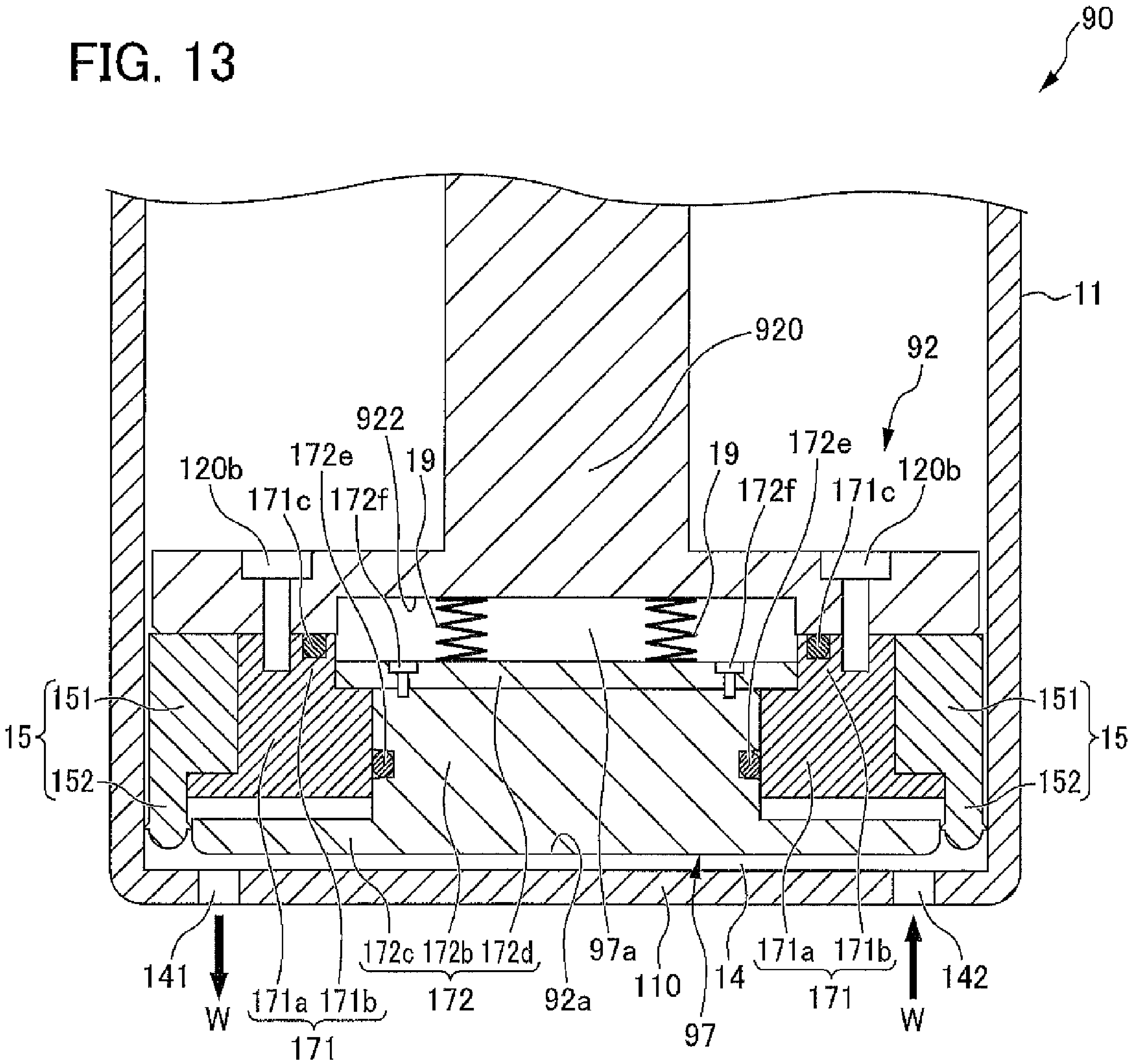

WHEN CLEANING HIGH VISCOSITY PAINT
LARGE
GAP
SMALL
POSITION OF THE EXTREME END SURFACE OF THE PISTON
ORIGINAL POSITION
LARGE
PRESSURE
SMALL
SUPPLY PRESSURE OF FLUID F (PREDETERMINED SETTING PRESSURE)
PRESSURE IN PAINT STORAGE
START CLEANING
TIME
END CLEANING

FIG. 13


90
11
920
92
922
172e
19
19
172e
120b
171c
172f
172f
171c
120b
151
15
152
151
15
152
141
W
171a
171b
171
172c
172b
172d
172
92a
97a
110
97
14
171a
171b
171
W
142

INTERMEDIATE STORAGE DEVICE OF ELECTROSTATIC COATING SYSTEM, METHOD FOR CLEANING THE SAME, AND METHOD FOR COATING

This application is based on and claims the benefit of priority from Japanese Patent Application Nos. 2012-048287 and 2012-264612, respectively filed on 5 Mar. 2012 and 3 Dec. 2012, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an intermediate storage device of an electrostatic coating system, a method for cleaning the same, and a method for coating.

2. Related Art

Conventionally, an electrostatic coating system of voltage block type is known as an electrostatic coating system for vehicle bodies (refer to Patent Document 1). In this electrostatic coating system, electrically-conductive paint is introduced into an intermediate storage device, which is insulated from ground potential, from a paint supply source and is stored temporarily. Thereafter, voltage block is provided by cleaning and drying the supply route that connects the intermediate storage device and the paint supply source, and the intermediate storage device and the paint supply source are insulated electrically. Then, electrostatic coating is applied to the object to be coated by applying high voltage to the electrically-conductive paint and supplying the paint to the coating gun in this state.

Meanwhile, when changing the coating color in the above-described electrostatic coating system, electrically-conductive paint of next coating color is introduced after cleaning the intermediate storage device. At this time, when the cleaning of the intermediate storage device is insufficient, the coating color to be painted next and the coating color last painted are mixed together. In addition, the cycle time lengthens if time is spent on cleaning in order to sufficiently clean the intermediate storage device. Patent Document 1 discloses injecting cleaning fluid into a cylinder chamber where paint is stored from an injection hole which is open to the cylinder chamber to clean the cylinder chamber and discharging from a discharge hole waste fluid that has undergone cleaning.

Patent Document 1: Japanese Unexamined Patent Application, Publication No. 2004-275977

SUMMARY OF THE INVENTION

However, the cleaning fluid injected into the cylinder chamber from an injection hole flows into a discharge hole while extruding the paint remaining in the cylinder chamber. That is, the paint remaining in the cylinder chamber serves as resistance to the flow of the cleaning fluid. At this time, the cleaning fluid flows through a shortest route that connects the injection hole and the discharge hole linearly while extruding the remained paint, and when the cleaning of the shortest route is completed, the cleaning fluid continues to flow through this shortest route in which resistance has became smaller. Therefore, there is a problem in that it takes time for cleaning other parts, especially, side parts between the injection hole and the discharge hole (Position P described in FIG. 4B, which will be described later).

In addition, paint has characteristics of having different viscosity for each type (paint type such as coating color, intermediate coating, and finishing coating). Therefore, according to the type of paint, it is necessary to adjust the supply pressure of the cleaning fluid and the depression position (cleaning position) of the piston and reduce the loss of the cleaning fluid and the paint. However, it is difficult to perform such adjustments appropriately for each type of paint.

The present invention has been achieved in view of the above and an object of the present invention is to provide an intermediate storage device of an electrostatic coating system that can clean efficiently, a method for cleaning the same, and a method for coating.

In order to accomplish the above-described object, an embodiment of the present invention provides an intermediate storage device (e.g., the below-described intermediate storage device **10**) of an electrostatic coating system (e.g., the below-described electrostatic coating system **1**), comprising: a cylinder (e.g., the below-described cylinder **11**) which is provided between a paint supply source (e.g., the below-described color switching valve mechanism **20**) and a coating gun (e.g., the below-described coating gun **60**) and stores paint; a piston (e.g., the below-described piston **12**) which can slide inside a cylinder chamber (e.g., the below-described cylinder chamber **14**) of the cylinder; a driving source (e.g., the below-described servo-motor **13**) which drives the piston. An intermediate storage device of an electrostatic coating system according to an embodiment of the present invention comprises: a first hole (e.g., the below-described first hole **141**) which is open to the cylinder chamber and is connected to the paint supply source; a second hole (e.g., the below-described second hole **142**) which is open to the cylinder chamber and is connected to the coating gun; a first cleaning means (e.g., the below-described control device **70**, first cleaning valve **21**, and second dumping valve **41**) which cleans the cylinder chamber by supplying cleaning fluid from the first hole and discharging from the second hole waste fluid that has undergone cleaning; a second cleaning means (e.g., the below-described control device **70**, second cleaning valve **51**, and first dumping valve **31**) which cleans the cylinder chamber by supplying cleaning fluid from the second hole and discharging from the first hole waste fluid that has undergone cleaning; and a switch means (e.g., the below-described control device **70**, first cleaning valve **21**, second dumping valve **41**, second cleaning valve **51**, and first dumping valve **31**) which switches between cleaning performed by the first cleaning means and cleaning performed by the second cleaning means.

In an intermediate storage device of the electrostatic coating system according to an embodiment of the present invention, there are provided: a first hole which is open to the cylinder chamber and is connected to the paint supply source; and a second hole which is open to the cylinder chamber and is connected to the coating gun. In addition, the cylinder chamber is cleaned by switching between supply of cleaning fluid from the first hole and supply of cleaning fluid from the second hole. If the cleaning fluid is supplied only from one hole as in a conventional technique, it takes time for cleaning the intermediate part at the side of the other hole (the below-described position P illustrated in FIG. **4**B). In contrast, according to the present invention, after supplying the cleaning fluid for a specific time period from one of the holes, the cleaning fluid is supplied for a specific time period from the other hole and thus the paint remaining near both holes can be discharged efficiently. Therefore, according to the present invention, it is possible to provide an intermediate storage device of an electrostatic coating system that can clean efficiently.

Here, it is preferable if the opening diameter of the first hole and the opening diameter of the second hole are different.

In this embodiment, the opening diameter of the first hole and the opening diameter of the second hole are different. Thereby, when the cleaning fluid is supplied from a hole having larger opening diameter and the waste fluid that has undergone cleaning is discharged from a hole having smaller opening diameter, pressure at the discharge side, that is, back pressure, increases. Therefore, it is possible to prevent the cleaning fluid from flowing only through portions where resistance is small to be discharged out and thus it is possible to clean the entire cylinder chamber efficiently.

Here, it is preferable if the device further includes an annular seal member which fits into an outer peripheral of the extreme end of the piston (e.g., the below-described a seal member **15**), and an extreme end surface of the seal member (e.g., the below-described extreme end surface **150** of the seal member **15**) is provided substantially in-plane with an extreme end surface of the piston (e.g., the below-described extreme end surface **12***a* of the piston).

In this embodiment, the extreme end surface of the annular seal member which fits into the outer peripheral of the extreme end of the piston is substantially in-plane with the extreme end surface of the piston. Accordingly, the length of the cylinder chamber where the paint is stored in the cylinder axis direction is substantially uniform. Therefore, the resistance with respect to the cleaning fluid that flows through the cylinder chamber is substantially uniform and the cylinder chamber can be cleaned more efficiently by uniformly distributing the cleaning fluid in the entire cylinder chamber.

Here, it is preferable to further include a driving source control means (e.g., the below-described control device **70**) which controls the driving source to drive the piston during the cleaning performed by the first cleaning means and the cleaning performed by the second cleaning means.

In this embodiment, the piston is driven when supplying the cleaning fluid from the first hole and when supplying the cleaning fluid from the second hole. Thereby, since the paint remaining in the cylinder chamber can be agitated to lower the viscosity by supplying the cleaning fluid while changing the volume of the cylinder chamber, the cylinder chamber can be cleaned more efficiently.

It is preferable to have a displacement mechanism (e.g., the below-described displacement mechanisms **17** and **97**) which displaces the position of the extreme end surface of the piston with respect to the cylinder by displacing the position of the extreme end surface of the piston with respect to the body of the piston (e.g., the below-described piston bodies **120** and **920**).

In an embodiment, there is provided a displacement mechanism which displaces the position of the extreme end surface of the piston with respect to the cylinder by displacing the position of the extreme end surface of the piston with respect to the body of the piston when the pressure in the intermediate storage device exceeds predetermined pressure by the cleaning fluid being filled in the intermediate storage device.

According to an embodiment, when the paint remaining in the intermediate storage device serves as resistance to the flow of the cleaning fluid and the pressure in the intermediate storage device increases to exceed the predetermined pressure at the time of cleaning, the position of the extreme end surface of the piston with respect to the cylinder is displaced automatically without controlling due to the displacement of the position of the extreme end surface of the piston with respect to the body of the piston. Thereby, since the volume in the intermediate storage device increases and the amount of the cleaning fluid with respect to the paint remaining in the intermediate storage device increases to reduce the viscosity of the paint, it is possible to improve cleaning efficiency. Therefore, according to the present invention, it is possible to clean inside the intermediate storage device effectively irrespective of the type of the paint.

Here, it is preferable to further include a control means (e.g., the below-described control device **70**) which controls a displacement mechanism (e.g., the below-described displacement mechanism **97**) such that the position of the extreme end surface of the piston (e.g., the below-described extreme end surface **92***a* of the piston) with respect to the body of the piston (e.g., the below-described piston body **920**) is not displaced during the coating.

In this embodiment, control is performed such that the position of the extreme end surface of the piston with respect to the body of the piston is not displaced during the coating, that is, when extruding the paint filled in the intermediate storage device.

According to this embodiment, since the position of the extreme end surface of the piston with respect to the body of the piston is not displaced during the coating, it is possible to supply exact amount of paint to the coating gun.

In addition, there is provided a method for cleaning an intermediate storage device of an electrostatic coating system including: a cylinder that is provided between a paint supply source and a coating gun; a piston which can slide inside a cylinder chamber of the cylinder and; a driving source which drives the piston. A method for cleaning an intermediate storage device of an electrostatic coating system according to this embodiment cleans the cylinder chamber by switching between the supply of cleaning fluid from a first hole which is open to the cylinder chamber and is connected to the paint supply source and the supply of cleaning fluid from a second hole which is open to the cylinder chamber and is connected to the coating gun.

Here, it is preferable to clean the cylinder chamber by making different the opening diameter of the first hole and the opening diameter of the second hole.

Here, it is preferable to clean the cylinder chamber by arranging the seal member such that the extreme end surface of the annular seal member which fits into the outer peripheral of the extreme end of the piston is substantially in-plane with the extreme end surface of the piston.

Here, it is preferable to clean the cylinder chamber by driving the piston with the driving source during the supply of the cleaning fluid from the first hole and during the supply of the cleaning fluid from the second hole.

The above methods for cleaning the intermediate storage device of the electrostatic coating systems exert the same advantageous effects as the above intermediate storage devices of the electrostatic coating system.

In addition, there is provided a method for coating that use an electrostatic coating system (e.g., the below-described electrostatic coating device **1**) including: a paint supply source (e.g., the below-described paint tank and the color switching valve mechanism **20**); a coating gun (e.g., the below-described coating gun **60**); and an intermediate storage device (e.g., the below-described intermediate storage devices **10** and **90**) provided between the coating gun and the paint supply source; wherein the intermediate storage device includes a cylinder (e.g., the below-described cylinder **11**) and a piston (e.g., the below-described pistons **12** and **92**) which can slide inside the cylinder, and the method includes: a step of filling the cleaning fluid (e.g., the below-described cleaning fluid W) in the cylinder chamber (e.g., the below-described cylinder chamber **14**) formed between the cylinder and the extreme end surface of the piston (e.g., the below-described extreme end surfaces **12***a* and **92***a*); and a step of displacing the position of the extreme end surface of the piston with respect to the cylinder.

In this method for coating, the cleaning fluid is filled in the intermediate storage device at the time of cleaning, and the position of the extreme end surface of the piston with respect to the cylinder is displaced. Thereby, as in the above embodiments, it is possible to clean inside the intermediate storage device effectively irrespective of the type of the paint.

According to the present invention, it is possible to provide an intermediate storage device of an electrostatic coating system that can clean efficiently, a method for cleaning the same, and a method for coating.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic structural diagram of an electrostatic coating system including an intermediate storage device according to a first embodiment;

FIG. **2** is a partial cross-sectional view showing a structure of the intermediate storage device according to the first embodiment;

FIGS. **3**A-**3**C depict diagrams for illustrating routes of the cleaning fluid, wherein FIG. **3**A is a diagram showing routes of the cleaning fluid when a supply hole and a discharge hole of the same opening diameter are provided at positions substantially symmetrical with each other with respect to the center of the extreme end of the cylinder near the periphery edge of the extreme end of the cylinder, and FIGS. **3**B and **3**C are diagrams showing the relation between the route resistance and the discharge resistance for each route;

FIGS. **4**A-**4**B depict diagrams for illustrating a first cleaning according to the first embodiment, wherein FIG. **4**A is a diagram showing the flow of the cleaning fluid when performing the first cleaning, and FIG. **4**B is a diagram showing a situation of the cleaning when performing the first cleaning;

FIGS. **5**A-**5**B depict diagrams for illustrating a second cleaning according to the first embodiment, wherein FIG. **5**A is a diagram showing the flow of the cleaning fluid when performing the second cleaning, and FIG. **5**B is a diagram showing a situation of the cleaning when performing the second cleaning;

FIGS. **6**A-**6**B depict diagrams showing the relation between the opening diameter of the first hole and the opening diameter of the second hole, wherein FIG. **6**A is a diagram showing a situation of the cleaning when the first hole and the second hole of the same opening diameter are provided, and FIG. **6**B is a diagram showing a situation of the cleaning when the opening diameter of the second hole is made smaller than the opening diameter of the first hole;

FIG. **7** is a partial cross-section enlarged view of the extreme end of the intermediate storage device according to a third embodiment;

FIGS. **8**A-**8**D depict cross-sectional views showing a situation of the cleaning upon sliding the piston when performing the first cleaning, wherein FIG. **8**A shows a situation when supply of the cleaning fluid from the first hole has begun, FIG. **8**B shows a situation when the piston is retreated with respect to the cylinder, FIG. **8**C shows a situation when the retreat of the piston with respect to the cylinder is stopped, and FIG. **8**D shows a situation when advancing the piston with respect to the cylinder;

FIG. **9** is an enlarged cross-sectional view of the intermediate storage device according to a fourth embodiment when the pressure in the cylinder chamber is lower than the supply pressure of the fluid supplied into the cylinder chamber at the time of cleaning the low viscosity paint;

FIG. **10** is an enlarged cross-sectional view of the intermediate storage device according to the fourth embodiment when the pressure in the cylinder chamber is higher than the supply pressure of the fluid supplied into the cylinder chamber at the time of cleaning the high viscosity paint;

FIG. **11** is a diagram showing the relation between the pressure in the cylinder chamber and the position of the extreme end surface of the piston at the time of cleaning the low viscosity paint;

FIG. **12** is a diagram showing the relation between the pressure in the cylinder chamber and the position of the extreme end surface of the piston at the time of cleaning the high viscosity paint; and

FIG. **13** is an enlarged cross-sectional view of the intermediate storage device according to the fifth embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will be described in detail with reference to the drawings. It should be noted that, in the description after that of the first embodiment, the same reference numeral is assigned for a structure in common with the first embodiment and the description thereof is omitted.

First Embodiment

FIG. **1** is a schematic structural diagram of an electrostatic coating system **1** including the intermediate storage device **10** according to the first embodiment of the present invention. The intermediate storage device **10** according to this embodiment can perform a method for cleaning according to an embodiment of the present invention.

The electrostatic coating system **1** includes: a color switching valve mechanism **20** including a first cleaning valve **21**; a first dumping valve **31**; a first trigger valve **32**; an intermediate storage device **10**; a second dumping valve **41**; a second trigger valve **42**; a second cleaning valve **51**; a coating gun **60**; and a control device **70**.

The color switching valve mechanism **20** is grounded and is connected to a first hole **141** of the intermediate storage device **10**, which will be described later. The color switching valve mechanism **20** includes a first cleaning valve **21** and a plurality of paint valves **22** and **23**.

A cleaning fluid tank and an air supply source (not illustrated) are connected to the first cleaning valve **21** and the first cleaning valve **21** controls the supply of the cleaning fluid W and the drying air A. A plurality of paint tanks (not illustrated) are connected to a plurality of paint valves **22** and **23** and the plurality of paint valves **22** and **23** control supply of the electrically-conductive paint of different paint colors.

A first discharge path **33** is connected to the first dumping valve **31**. By the second cleaning valve **51**, which will be described later, the cleaning fluid W supplied to the cylinder chamber **14** of the intermediate storage device **10**, which will be described later, cleans the cylinder chamber **14** to become waste fluid and is discharged through the first dumping valve **31** and the first discharge path **33**.

The first trigger valve **32** controls the supply of the electrically-conductive paint from the plurality of paint valves **22** and **23** of the color switching valve mechanism **20**. In addition, the first trigger valve **32** controls the supply of the cleaning fluid W and the drying air A from the first cleaning valve **21** of the color switching valve mechanism **20**.

The intermediate storage device **10** includes the cylinder **11**, the piston **12**, and the servo-motor **13**. In the present embodiment, the intermediate storage device **10** is provided in a robot arm (not illustrated) and its direction can be changed freely.

The cylinder **11** is substantially cylindrical-shaped and is made of insulating resin. In the cylinder **11**, the cylinder chamber **14** in which electrically-conductive paint is stored is formed by the piston **12**. The first hole **141** and the second hole **142** which are open to the cylinder chamber **14** are formed at the extreme end **110** of the cylinder **11**.

The first hole **141** is connected to the color switching valve mechanism **20**, and the second hole **142** is connected to the coating gun **60**, which will be described later.

The piston **12** is made of insulating resin and the piston rod **121** is connected to the piston **12**. The servo-motor **13** is connected to the piston rod **121** through a ball screw mechanism (not illustrated) and the piston **12** can slide inside the cylinder chamber **14** by driving the servo-motor **13**.

A voltage block mechanism (not illustrated) is provided between the color switching valve mechanism **20** and the intermediate storage device **10**. As a result of the color switching valve mechanism **20** and the intermediate storage device **10** being insulated electrically with the voltage block mechanism, it is possible to apply high voltage to the electrically-conductive paint by a coating gun **60**, which will be described later, connected to the intermediate storage device **10**.

The second discharge path **43** is connected to the second dumping valve **41**. By the first cleaning valve **21**, the cleaning fluid W supplied to the cylinder chamber **14** of the intermediate storage device **10** cleans the cylinder chamber **14** to change into waste fluid and is discharged through the second dumping valve **41** and the second discharge path **43**.

The second trigger valve **42** controls the supply of the electrically-conductive paint to the coating gun **60**, which will be described later. In addition, The second trigger valve **42** controls the supply of the cleaning fluid W and the drying air A from the second cleaning valve **51**, which will be described later.

The second cleaning valve **51** is connected to the cleaning fluid tank and the air supply source (not illustrated) and controls the supply of the cleaning fluid W and the drying air A.

The coating gun **60** is connected to the second hole **142** of the intermediate storage device **10**. The coating gun **60** is provided in the robot arm (not illustrated) and includes a high voltage application unit (not illustrated). The electrically-conductive paint supplied to the coating gun **60** through the second trigger valve **42** is blown off from the extreme end of the coating gun **60** in a situation where high voltage is applied by the high voltage application unit.

The control device **70** controls the color switching valve mechanism **20**, the first dumping valve **31**, the first trigger valve **32**, the intermediate storage device **10**, the second dumping valve **41**, the second trigger valve **42**, the second cleaning valve **51**, and the coating gun **60**. Specifically, the control device **70** controls the supply and the blowoff of the electrically-conductive paint and the supply and the discharge of the cleaning fluid W and the drying air A by carrying out opening and closing control of the valves, drive control of the servo-motor **13** of the intermediate storage device **10**, and drive control of the coating gun **60**. Thereby, it is possible to perform electrostatic coating and cleaning after performing the electrostatic coating and therefore it is possible to switch the coating color.

It should be noted that the control device **70** includes a first cleaning unit which performs a first cleaning that supplies the cleaning fluid W from a first hole **141**, and a second cleaning unit which performs a second cleaning that supplies the cleaning fluid W from a second hole **142**. In addition, the control device **70** includes a switching unit which performs switching between the first cleaning and the second cleaning, and a driving source control unit which performs drive control of the servo-motor **13** as a driving source.

Next, the intermediate storage device **10** according to the present embodiment will be described in more detail.

FIG. **2** is a partial cross-sectional view showing a structure of the intermediate storage device **10**. More specifically, FIG. **2** shows the intermediate storage device **10** at the time of the cleaning. As shown in FIG. **2**, at the time of the cleaning, the piston **12** slides until near the extreme end **110** of the cylinder **11**. Therefore, the cylinder chamber **14** is formed by slight clearance between the extreme end surface **12***a* of the piston **12** and the extreme end **110** of the cylinder **11**, and electrically-conductive paint remains in the cylinder chamber **14** having small volume.

As described above, the piston rod **121** and the servo-motor **13** are connected through a ball screw mechanism **131**. Thereby, as a result of the rotary motion of the servo-motor **13** being converted into rectilinear motion by the ball screw mechanism **131**, the piston rod **121** advances and retreats with respect to the cylinder **11** and thus the piston **12** slides inside the cylinder chamber **14**.

An annular seal member **15** is fit into the outer peripheral of the extreme end of the piston **12**. The seal member **15** has a structure where an O-ring **152** is buried at the extreme end side of the sealing member body **151** made of insulating resin (for example, made of Teflon (registered trademark)).

In addition, the first hole **141** connected to the color switching valve mechanism **20** through the connecting member **143** and the second hole **142** connected to the coating gun **60** through the connecting member **143** are formed near the periphery edge of the extreme end **110** of the cylinder **11** at positions substantially symmetrical with each other with respect to the axis of the cylinder **11**. In addition, the first hole **141** and the second hole **142** are respectively provided such that the position of the cylinder **11** in the radial direction is near the boundary between the seal member **15**, on which electrically-conductive paint tends to remain, and the outer peripheral of the extreme end of the piston **12**. Thereby, since the cleaning fluid W can be supplied toward near such boundary, it is possible to improve cleaning efficiency.

Here, FIGS. **3**A-**3**C depict diagrams for illustrating routes of the cleaning fluid, wherein FIG. **3**A is a diagram showing routes of the cleaning fluid W when a supply hole and a discharge hole having the same opening diameter are provided near the periphery edge of the extreme end **110** of the cylinder **11** in positions substantially symmetrical with each other with respect to the center of the extreme end **110** of the cylinder **11**. More specifically, FIG. **3**A shows a view of the cylinder chamber **14** at the time of cleaning from the base end side of the cylinder **11**.

As shown in FIG. **3**A, a route that extends substantially linearly through substantially center of the extreme end **110** of the cylinder **11** from the supply hole **91** where the cleaning fluid W is supplied and goes to the discharge hole **92** where the cleaning fluid W is discharged is assumed as Route X. In addition, a route that extends in a curvy shape from the supply hole **91** through near the periphery edge of the extreme end **110** of the cylinder **11** and goes to the discharge hole **92** (i.e., a route corresponding to the position where the seal member **15** is arranged) is assumed as Route Z; and a route that extends in a curvy shape from the supply hole **91** through between Route A and Route C and goes to the discharge hole **92** is assumed as Route Y.

FIGS. **3**B and **3**C are diagrams showing the relation of route resistance and the discharge resistance for each route. Here, discharge resistance represents resistance at the time when flowing through the discharge hole **92** and indicates magnitude of so-called back pressure. In addition, if a route that has route resistance larger than the discharge resistance, it means that the cleaning fluid W is hard to flow. Therefore, in the case of FIG. **3**B, since the route resistance in Route Y is the largest and is larger than the discharge resistance, it can be recognized that the cleaning fluid W is hard to flow through Route Y. In contrast, since the route resistance is smaller than the discharge resistance in Route X and Route Z, it can be recognized that the cleaning fluid W is easy to flow in these routes. Meanwhile, in the case of FIG. **3**C, since route resistance in Route Y is smaller than the discharge resistance, it can be recognized that the cleaning fluid W is easy to flow also in Route Y.

It should be noted that the reason why the route resistance in Route Z is smaller than the route resistance in Route X is the following. That is, although Route Z has route length longer than Route X, the clearance between the extreme end **110** of the cylinder **11** and the annular seal member **15** fitting into the extreme end periphery of the piston **12** is larger than the clearance between the extreme end **110** of the cylinder **11** and the extreme end surface **12***a* of the piston **12**.

Usually, the cleaning fluid W supplied to the cylinder chamber **14** from the supply hole **91** flows into the discharge hole **92** while extruding the electrically-conductive paint remaining in the cylinder chamber **14**. That is, the electrically-conductive paint remaining in the cylinder chamber **14** serves as resistance to the flow of the cleaning fluid W. Here, the cleaning fluid W flows through Route X and Route Z that have small route resistance while extruding the remaining electrically-conductive paint and thus when the cleaning of Route X and Route Z is completed, the cleaning fluid W continues to flow through Route X and Route Z in which resistance has become small. Therefore, cleaning of the electrically-conductive paint remaining in Route Y is promoted by an effect caused by the difference in speed at an interface with the cleaning fluid W that flows through Route X and Route Z and a dissolution effect of the electrically-conductive paint caused by the cleaning fluid at this interface.

However, since it takes time for the physical extrusion in this cleaning, it takes time for cleaning Route Y, especially near the discharge hole **92**. In addition, considering the structure of the cylinder **11**, the inner diameter of the cylinder **11** is far larger than the opening diameter of the supply hole **91** and the discharge hole **92**, and this tendency is more significant as the inner diameter of the cylinder **11** becomes larger as a result of the volume of the cylinder **11** becoming larger and thus it takes time for the cleaning.

Therefore, in the present embodiment, in order to improve the cleaning efficiency of the cylinder chamber **14**, the cylinder chamber **14** is cleaned by switching with a switching unit of the control device **70** between a first cleaning which is performed by a first cleaning unit and supplies the cleaning fluid W from the first hole **141** and a second cleaning which is performed by a second cleaning unit and supplies the cleaning fluid W from the second hole **142**.

FIGS. **4**A-**4**B depict diagrams for illustrating the first cleaning according to the present embodiment, wherein FIG. **4**A is a diagram showing the flow of the cleaning fluid W when performing the first cleaning. As shown in FIG. **4**A, in the first cleaning, the cylinder chamber **14** is cleaned by supplying the cleaning fluid W from the first hole **141** by the first cleaning valve **21** of the color switching valve mechanism **20** and discharging from the second hole **142** the waste fluid that has undergone cleaning. At this time, the switching unit of the control device **70** performs the first cleaning by closing the first dumping valve **31** and the second cleaning valve **51** and opening the first cleaning valve **21**, the first trigger valve **32**, and the second dumping valve **41**.

FIG. **4**B is a diagram showing a situation of the cleaning when performing the first cleaning. More specifically, FIG. **4**B shows a view of the cylinder chamber **14** when performing the first cleaning from the base end side of the cylinder **11**. As shown in FIG. **4**B, the cleaning fluid W supplied from the first hole **141** flows through Route X and Route Z and is discharged from the second hole **142** as described above. In addition, at this time, although the pressure of the cleaning fluid W is propagated to the circumference substantially uniformly near the first hole **141** at the supply side, the pressure is biased towards the discharge direction gradually as a result of the resistance of the electrically-conductive paint. Therefore, a large amount of electrically-conductive paint P remains between Route X and Route Z especially near the second hole **142** at the discharge side.

FIGS. **5**A-**5**B depict diagrams for illustrating the second cleaning according to the present embodiment, wherein FIG. **5**A is a diagram showing the flow of the cleaning fluid W when performing the second cleaning. As shown in FIG. **5**A, in the second cleaning, the cylinder chamber **14** is cleaned by supplying the cleaning fluid W from the second hole **142** with the second cleaning valve **51** and discharging from the first hole **141** the waste fluid that has undergone cleaning. Here, the switching unit of the control device **70** performs the second cleaning by closing the first cleaning valve **21**, the first trigger valve **32**, and the second dumping valve **41**, and opening the first dumping valve **31** and the second cleaning valve **51**.

FIG. **5**B is a diagram showing a situation of the cleaning when performing the second cleaning. More specifically, FIG. **5**B shows a view of the cylinder chamber **14** when performing the second cleaning from the base end side of the cylinder **11**. As shown in FIG. **5**B, the cleaning fluid W supplied from the second hole **142** flows through Route X and Route Z and is discharged from the first hole **141** as described above. In addition, at this time, since the pressure of the cleaning fluid W is propagated to the circumference substantially uniformly near the second hole **142** of the supply side, the electrically-conductive paint P that has remained largely near the second hole **142** after the first cleaning is performed is extruded to the first hole **141** at the discharge side and discharged out. Thereby, the entire cylinder chamber **14** is cleaned efficiently.

It should be noted that the first cleaning may be further performed after the second cleaning, and the first cleaning and the second cleaning may be repeated alternately. Thereby, the cylinder chamber **14** can be cleaned more efficiently within a range that does not take an excessively long cycle time.

In addition, the duration time of the second cleaning may be shorter than the duration time of the first cleaning. This is because the dissolution of the electrically-conductive paint P that had remained is partly advanced to lower its viscosity and thus it is possible to extrude the electrically-conductive paint P easily.

The electrostatic coating system **1** including the intermediate storage device **10** according to the present embodiment operates as follows.

First, with the control device **70**, the first dumping valve **31**, the second dumping valve **41**, and the second trigger valve **42** are opened and one of the paint valves and the first trigger valve are opened. In addition, the servo-motor **13** of the intermediate storage device **10** is driven by the driving source control unit of the control device **70**. Thereby, the electrically-conductive paint of predetermined coating color is pressure-fed into the cylinder chamber **14** of the intermediate storage device **10** and thus the electrically-conductive paint is supplied to the second trigger valve **42**.

Subsequently, when the filling of the electrically-conductive paint into the cylinder chamber **14** is completed, a voltage block mechanism (not illustrated) is controlled by the control device **70** such that the color switching valve mechanism **20** and the intermediate storage device **10** are electrically insulated.

Next, with the control device **70**, the second trigger valve **42** is opened and the piston **12** is advanced with respect to the cylinder **11** by a drive action of the servo-motor **13**. As a result, the electrically-conductive paint stored in the cylinder chamber **14** is pressure-fed towards the coating gun **60**. High voltage is applied at a high voltage application unit onto the electrically-conductive paint pressure-fed by the coating gun **60** and at this situation, the electrically-conductive paint is blown off from the extreme end of the coating gun **60** in this state. Thereby, electrostatic coating of the electrically-conductive paint is carried out with respect to the object to be coated.

When newly coating the electrically-conductive paint of different coating color after the electrostatic coating is completed, the second trigger valve **42** is closed with the control device **70** and application of high voltage to the coating gun **60** is canceled. In addition, electric insulation between the color switching valve mechanism **20** and the intermediate storage device **10** by the voltage block mechanism is canceled.

Subsequently, by the switching unit of the control device **70**, the first dumping valve **31** and the second cleaning valve **51** are closed, and the first cleaning valve **21**, the first trigger valve **32**, and the second dumping valve **41** are opened. Thereby, the first cleaning that cleans the cylinder chamber **14** is performed by supplying the cleaning fluid W from the first hole **141** and discharging from the second hole **142** the waste fluid that has undergone cleaning.

After performing the first cleaning for predetermined time period (time period longer than the duration time of the second cleaning in the present embodiment), the first cleaning valve **21**, the first trigger valve **32**, and the second dumping valve **41** are closed and the first dumping valve **31** and the second cleaning valve **51** are opened by the switching unit of the control device **70**. Thereby, the second cleaning that cleans the cylinder chamber **14** is performed by supplying the cleaning fluid W from the second hole **142** and discharging from the first hole **141** the waste fluid that has undergone cleaning.

As described above, after the cylinder chamber **14** is cleaned efficiently, electrostatic coating is performed by newly supplying electrically-conductive paint of different coating color with the same procedure as the above-described procedure.

The present embodiment exerts the following advantageous effects.

In the present embodiment, the first hole **141** which is open to the cylinder chamber **14** and is connected to the color switching valve mechanism **20** which serves as a paint supply source and the second hole **142** which is open to the cylinder chamber **14** and is connected to the coating gun **60** are provided in the intermediate storage device **10** of the electrostatic coating system **1**. In addition, the cylinder chamber **14** is cleaned while supply of the cleaning fluid W from the first hole **141** and supply of the cleaning fluid W from the second hole **142** are switched. If the cleaning fluid W is supplied from only one of the holes as in a conventional technique, it takes time for cleaning near the other hole. In contrast, according to the present embodiment, since the cleaning fluid W is supplied for a specific time period from the second hole **142** after supplying the cleaning fluid W from the first hole **141** for a specific time period, the electrically-conductive paint remaining near both holes can be discharged efficiently. Therefore, according to the present embodiment, it is possible to provide an intermediate storage device **10** of the electrostatic coating system **1** that can clean efficiently.

Second Embodiment

This embodiment is different from the first embodiment in that the opening diameter of the first hole **141** and the opening diameter of the second hole **142** are different in order to improve cleaning efficiency of the cylinder chamber **14**, and other structure is the same as that of the first embodiment. Specifically, in the present embodiment, the opening diameter of the second hole **142*a*** is set smaller than the opening diameter of the first hole **141*a***.

Here, in order to improve cleaning efficiency of the cylinder chamber **14**, it is important to diffuse the flow of the cleaning fluid W inside the cylinder chamber **14**, and this is made possible by controlling the flow of the cleaning fluid W to the discharge side. Specifically, as a result of raising the back pressure at the discharge side, the residence time period of the cleaning fluid W in a state where the pressure when the cleaning fluid W is supplied to the cylinder chamber **14** is maintained becomes long. If the residence time period of the cleaning fluid W becomes long, it is easier to dissolve the electrically-conductive paint in the resided cleaning fluid W and thus the cleaning efficiency improves.

A conventional technique is known which suppresses the flow of the cleaning fluid W and has longer residence time period of the cleaning fluid W and thus improves cleaning efficiency by making the supply direction and the discharge direction of the cleaning fluid W different. However, with this technique, when an intermediate storage device is provided in a robot arm, for example, and its direction is freely changed, it is not possible to obtain advantageous effects due to the influence of gravity. This becomes increasingly significant if the diameter of the cylinder is larger.

FIGS. **6**A-**6**B depict diagrams showing the relation between the opening diameter of the first hole and the opening diameter of the second hole. FIG. **6**A is a diagram showing a situation of the cleaning when the first hole **141** and the second hole **142** having the same opening diameter are provided as in the above-described first embodiment; and FIG. **6**B is a diagram showing a situation of the cleaning when the opening diameter of the second hole **142*a*** is smaller than the opening diameter of the first hole **141*a***. Such FIGS. **6**A and **6**B are views of the cylinder chamber **14** from the base end side of the cylinder **11** at the time of cleaning.

As shown in FIG. **6**A, when the first hole **141** and the second hole **142** having the same opening diameter are provided, the cleaning fluid W supplied from the first hole **141** flows through Route X and Route Z and is discharged from the second hole **142** as described above. Meanwhile, as shown in FIG. **6**B, in the present embodiment where the opening diameter of the second hole **142*a*** is smaller than the opening diameter of the first hole **141*a***, the pressure at the discharge side, that is, the back pressure, increases. Therefore, although the flow rate itself of the cleaning fluid W to be discharged decreases, the cleaning fluid W flows also in Route Y where the cleaning fluid W is hard to flow. Thereby, it is possible to prevent the cleaning fluid W from being discharged by flowing only parts where the resistance is small and thus the entire cylinder chamber **14** can be cleaned more efficiently.

In the present embodiment, the opening diameter of the second hole **142***a* is set smaller than the opening diameter of the first hole **141***a*. This is because the duration time of the first cleaning is set longer than the duration time of the second cleaning. That is, in the present embodiment, the above advantageous effect can be sufficiently exerted by supplying the cleaning fluid W for a long time in a state where the back pressure is raised.

However, the present invention is not limited to this and the opening diameter of the first hole **141***a* may be set smaller than the opening diameter of the second hole **142***a*.

Third Embodiment

This embodiment is different from the first embodiment in that, in order to improve cleaning efficiency of the cylinder chamber **14**, an annular seal member **15** which fits into the outer peripheral of the extreme end of the piston **12** is arranged such that its extreme end surface **150** is in-plane with the extreme end surface **12***a* of the piston **12**, and other structure is the same as that of the first embodiment.

Here, in order to exert the extrusion force of the cleaning fluid W to the utmost, it is important to minimize the amount of the electrically-conductive paint P remaining in the cylinder chamber **14**. Therefore, it is desired to minimize the size of the cylinder chamber **14** formed by the clearance between the extreme end surface **12***a* of the piston **12** and the extreme end **110** of the cylinder **11** while securing the flow of the cleaning fluid W at the time of the cleaning. In addition, it is desired to secure clearance equivalent to that of the center part of the piston **12** in the radial direction in order to make the flow of the cleaning fluid W uniform in the outer peripheral of the extreme end of the piston **12** where the annular seal member **15** is located.

FIG. **7** is a partial cross-section enlarged view of an extreme end of the intermediate storage device **10** according to the present embodiment. As shown in FIG. **7**, in the present embodiment, the cylinder chamber **14** is formed by slight clearance between the extreme end surface **12***a* of the piston **12** and the extreme end **110** of the cylinder **11**. In addition, the extreme end surface **150** of the annular seal member **15** fit into the outer peripheral of the extreme end of the piston **12** is in-plane with the extreme end surface **12***a* of the piston **12**. More specifically, the annular extreme end surface **150** in the buried part of the O-ring **152** is in-plane with the extreme end surface **12***a* of the piston **12**.

Thereby, the length of the cylinder chamber **14** where the electrically-conductive paint is stored in the direction of the cylinder axis can be made substantially uniform while securing the flow of the cleaning fluid W. Therefore, the resistance with respect to the cleaning fluid W that flows through the cylinder chamber **14** is substantially uniform and the cleaning fluid W is distributed substantially uniformly in the entire cylinder chamber **14** and thus the entire cylinder chamber **14** can be efficiently cleaned.

Fourth Embodiment

This embodiment is different from the first embodiment in that, in order to improve cleaning efficiency of the cylinder chamber **14**, the piston **12** slides by driving the servo-motor **13** during the first cleaning and the second cleaning with the driving source control unit of the control device **70**, and other structure is the same as that of the first embodiment.

Here, in order to improve cleaning efficiency of the cylinder chamber **14**, it is important to agitate inside the cylinder chamber **14** actively. Conventional techniques are known which promote agitation with an agitator, a straightening vane, or the like but since the structure is complicated in these techniques, it takes considerable time for the cleaning.

FIGS. **8**A-**8**D depict cross-sectional views showing situations of cleaning upon sliding the piston **12** during the first cleaning.

First, FIG. **8**A shows a situation when the supply of the cleaning fluid W from the first hole **141** has begun. As described above, a large amount of electrically-conductive paint P remaining in the cylinder chamber **14** exists near the second hole **142**.

Next, FIG. **8**B shows a situation where the piston **12** slides during the first cleaning and retreats with respect to the cylinder **11**. It can be recognized that, as a result of the piston **12** being retreated, the clearance between the extreme end surface **12***a* of the piston **12** and the extreme end **110** of the cylinder **11** becomes large and thus the volume of the cylinder chamber **14** has become larger. Thereby, a large amount of cleaning fluid is introduced into the cylinder chamber **14**.

Next, FIG. **8**C shows a situation where the retreat of the piston **12** with respect to the cylinder **11** has stopped. It can be recognized that the remaining electrically-conductive paint P is gradually spread in the entire cylinder chamber **14** by an agitation effect as a result of the piston **12** being retreated and the volume of the cylinder chamber **14** being increased. Thereby, the contact area between the remained electrically-conductive paint P and the cleaning fluid W increases and thus the viscosity of the electrically-conductive paint P is lowered by the dissolving ability of the cleaning fluid W.

Next, FIG. **8**D shows a situation of sliding the piston **12** again and advancing the piston **12** with respect to the cylinder **11**. It can be recognized that, as the piston **12** moves forward, the clearance between the extreme end surface **12***a* of the piston **12** and the extreme end **110** of the cylinder **11** becomes small and thus the volume of the cylinder chamber **14** has become smaller. At this time, the electrically-conductive paint P whose viscosity has been already reduced is further diffused in the entire cylinder chamber **14**.

As described above, by supplying the cleaning fluid W while sliding the piston **12** and changing the volume of the cylinder chamber **14**, it is possible to agitate the electrically-conductive paint P that remains in the cylinder chamber **14** to thereby reduce the viscosity and thus it is possible to clean the entire cylinder chamber **14** more efficiently.

In the present embodiment, the piston **12** slides during the first cleaning. This is because the duration time of the first cleaning is set longer than the duration time of the second cleaning. That is, in the present embodiment, the above-described advantageous effect can fully be exerted by supplying for a longer time the cleaning fluid W while changing the volume of the cylinder chamber **14**.

However, the present invention is not limited to this and the piston **12** may slide during the second cleaning.

Fifth Embodiment

FIG. **1** is a schematic structural diagram of the electrostatic coating device **1** according to the fifth embodiment of the present invention also. The electrostatic coating device **1** according to this embodiment can perform a method for coating according to an embodiment.

The electrostatic coating device **1** includes: an intermediate storage device **10**; a color switching valve mechanism **20** including a first cleaning valve **21**; a first dumping valve **31**; a first trigger valve **32**; a second dumping valve **41**; a second trigger valve **42**; a second cleaning valve **51**; a coating gun **60**; and a control device **70**.

The color switching valve mechanism **20** is grounded and connected to a first hole **141** of the intermediate storage device **10** described in detail in the latter part. The color switching valve mechanism **20** includes the first cleaning valve **21** and a plurality of paint valves **22** and **23**.

A cleaning fluid tank and an air supply source (not illustrated) are connected and the first cleaning valve **21** controls the supply of the cleaning fluid W and the drying air A. A plurality of paint tanks (not illustrated) are connected to the plurality of paint valves **22** and **23** and the plurality of paint valves **22** and **23** control supply of electrically-conductive paint of different paint colors.

The second discharge path **43** is connected to the second dumping valve **41**. The cleaning fluid W that is supplied to the cylinder chamber **14** of the intermediate storage device **10**, which will be described later, by the first cleaning valve **21** cleans the cylinder chamber **14** to become waste fluid and is discharged through the second dumping valve **41** and the second discharge path **43**.

The first trigger valve **32** controls the supply of the electrically-conductive paint from the plurality of paint valves **22** and **23** of the color switching valve mechanism **20**. In addition, the first trigger valve **32** controls the supply of the cleaning fluid W and the drying air A from the first cleaning valve **21** of the color switching valve mechanism **20**.

The intermediate storage device **10** includes a cylinder **11**, a piston **12** and a servo-motor **13**. In the present embodiment, the intermediate storage device **10** is included in a robot arm (not illustrated) and its direction can be changed freely.

The cylinder **11** is substantially cylindrical-shaped and is made of insulating resin. In the cylinder **11**, a cylinder chamber **14** where the electrically-conductive paint is stored is formed inside the extreme end surface **12***a* of the piston **12**. The first hole **141** and the second hole **142**, which are open to the cylinder chamber **14**, are formed at the extreme end **110** of the cylinder **11**.

The first hole **141** is connected to the color switching valve mechanism **20** and the second hole **142** is connected to the coating gun **60**, which will be described later.

The piston **12** is made of insulating resin and includes a piston body **120** as will be described later. The servo-motor **13** is connected to the piston body **120** via a ball screw mechanism (not illustrated). By driving the servo-motor **13**, the rotary motion of the servo-motor **13** is converted into rectilinear motion by the ball screw mechanism. Thereby, the piston **12** can slide inside the cylinder **11** by the piston **12** advancing and retreating with respect to the cylinder **11**.

A voltage block mechanism (not illustrated) is provided between the color switching valve mechanism **20** and the intermediate storage device **10**. By way of this voltage blocking mechanism, the color switching valve mechanism **20** and the intermediate storage device **10** are insulated electrically with each other and thus it is possible to apply high voltage to the electrically-conductive paint by a coating gun **60**, which will be described later, and is connected to the intermediate storage device **10**.

The second trigger valve **42** controls the supply of the electrically-conductive paint to the coating gun **60**, which will be described later. In addition, the second trigger valve **42** controls the supply of the cleaning fluid W from the second cleaning valve **51** described later and the drying air A.

The cleaning fluid tank and air supply source (not illustrated) are connected to the second cleaning valve **51** and the second cleaning valve **51** controls the supply of the cleaning fluid W and the drying air A.

The coating gun **60** is connected to the second hole **142** of the intermediate storage device **10**. The coating gun **60** is provided in the robot arm (not illustrated) and includes the high voltage application unit (not illustrated). The electrically-conductive paint supplied to the coating gun **60** through the second trigger valve **42** is blown off from the extreme end of the coating gun **60** in a state where high voltage is applied by the high voltage application unit.

The control device **70** controls the color switching valve mechanism **20**, the first dumping valve **31**, the first trigger valve **32**, the intermediate storage device **10**, the second dumping valve **41**, the second trigger valve **42**, the second cleaning valve **51** and the coating gun **60**. Specifically, the control device **70** controls the supply and injection of the electrically-conductive paint and supply and discharge of the cleaning fluid W and the drying air A by performing opening and closing control of each valve, drive control of the servo-motor **13** of the intermediate storage device **10**, drive control of the driving source of the displacement mechanism **17** described later and drive control of the coating gun **60**. Thereby, it is possible to perform electrostatic coating and cleaning after the electrostatic coating is performed and thus it is possible to switch the coating color.

It should be noted that, at the time of the cleaning, the control device **70** controls the servo-motor **13** to slide the piston **12** until near the extreme end **110** of the cylinder **11** and stop the drive of the piston **12** and then cleaning is performed in this state.

In addition, during the coating, the control device **70** controls the servo-motor **13** to perform coating while advancing the piston **12** with respect to the cylinder **11**.

Hereafter, the intermediate storage device **10** according to the present embodiment will be described in detail.

FIG. **9** and FIG. **10** are enlarged cross-sectional views showing the structure of the intermediate storage device **10** according to the present embodiment. More specifically, FIG. **9** is an enlarged cross-sectional view of the extreme end of the intermediate storage device **10** when the pressure inside the cylinder chamber **14** is lower than predetermined fixed supply pressure of the fluid F supplied into the cylinder chamber **14** at the time of cleaning the low viscosity paint; and FIG. **10** is an enlarged cross-sectional view of the extreme end of the intermediate storage device **10** when the pressure in the cylinder chamber **14** is higher than the predetermined fixed supply pressure of the fluid F supplied into the cylinder chamber **14** at the time of cleaning the high viscosity paint.

As shown in FIG. **9** and FIG. **10**, the piston **12** includes a piston body **120** and a displacement mechanism **17**. The position of the extreme end surface **12***a* of the piston **12** is displaced with respect to the cylinder **11** by the displacement mechanism **17** displacing the position of the extreme end surface **12***a* of the piston **12** with respect to the piston body **120**.

The piston body **120** can slide inside the cylinder **11**.

The displacement mechanism **17** is provided at the extreme end of the piston body **120**. The displacement mechanism **17** includes: a cylinder part **171**; a displacing part **172**; and a driving source that displaces the displacing part **172** (not illustrated).

The cylinder part **171** extends from the extreme end surface **120***a* of the piston body **120** toward the extreme end **110** of the cylinder **11** and is fixed onto the extreme end surface **120***a* with a plurality of bolts **120***b*. The cylinder part **171** includes: a cylinder small diameter part **171***a* which is formed at the extreme end side and has inner diameter smaller than that of the below-described cylinder large diameter part **171***b*; and a cylinder large diameter part **171***b* which is formed at the base end side and has an inner diameter larger than that of the cylinder small diameter part **171***a*.

The seal part **171***c* including a circular O-ring is fit onto the base end side of the cylinder part **171** that contacts with the extreme end surface **120***a* of the piston body **120**. Thereby, it is possible to avoid the fluid F supplied from a driving source, which will be described later, from leaking outside.

The displacing part **172** includes: a displacing part body **172***b*; an extreme end flange part **172***c*; and a base end flange part **172***d*.

The displacing part body **172***b* is formed in a substantially cylindrical shape and can slide inside the cylinder part **171**. More specifically, the displacing part body **172***b* can slide inside the cylinder small diameter part **171***a* of the cylinder part **171**. A seal part **172***e* which includes a circular O-ring is fit onto the periphery of the displacing part body **172***b*. Thereby, it is possible to avoid the fluid F supplied from the driving source, which will be described later, from leaking outside.

The extreme end flange part **172***c* has a flange which is formed at an extreme end of the displacing part body **172***b* and extends outward in the radial direction in the entire circumference. Here, an extreme end surface **12***a* of the piston **12** in the present embodiment indicates an extreme end surface **172***a* (extreme end surface of the extreme end flange part **172***c*) of the displacing part **172**.

It should be noted that the above-described cylinder chamber **14** is formed by a space surrounded by the extreme end surface **12***a* (**172***a*) of the piston **12** and the extreme end **110** of the cylinder **11**.

The base end flange part **172***d* is formed at the base end of the displacing part body **172***b* and has a flange extending the entire circumference in the radial direction. The base end flange part **172***d* is fixed onto the base end surface of the displacing part body **172***b* with a plurality of bolts **172***f*. The base end flange part **172***d* can slide inside the cylinder large diameter part **171***b*. Since the diameter of the base end flange part **172***d* is formed larger than the inner diameter of the cylinder small diameter part **171***a*, the base end flange part **172***d* slides only the inside of the cylinder large diameter part **171***b*. Thereby, the displacement distance of the displacing part **172** is regulated.

It should be noted that the fluid room **17***a* to which the fluid F, which will be described later, is supplied is formed by a space between the base end side of the base end flange part **172***d* and the extreme end surface **120***a* of the piston body **120**.

As a driving source of the displacement mechanism **17**, there is provided a fluid supply source (not illustrated) which supplies the fluid F. Examples of the fluid F include air and water. The fluid supply source supplies the fluid F to the fluid room **17***a* through a fluid supply path **120***c* which extends inside the piston body **120** in the axial direction of the piston body **120** and is open to the extreme end surface **120***a*.

The supply pressure of the fluid F supplied by the fluid supply source is controlled by the control device **70**. Specifically, at the time of cleaning, the supply pressure of the fluid F is controlled at predetermined fixed supply pressure. In addition, the supply pressure of the fluid F is controlled to always have supply pressure higher than the pressure in the cylinder chamber **14** at the time of coating.

The circular seal part **15** is fit onto the extreme end periphery of the piston **12**, specifically the circular seal part **15** is fit onto the periphery of the cylinder part **171** having the above structure. The seal part **15** includes: a seal body **151** made of insulating resin (for example, made of Teflon (registered trademark)); and a seal extreme end **152** which projects from the extreme end periphery of the seal body **151** to the extreme end side. Thereby, it is possible to avoid the electrically-conductive paint and the cleaning fluid W supplied into the cylinder chamber **14** from leaking outside.

The first hole **141** connected to the color switching valve mechanism **20** and the second hole **142** connected to the coating gun **60** are formed near the periphery edge of the extreme end **110** of the cylinder **11** at positions substantially symmetrical with each other with respect to the medial axis of the cylinder **11**. In addition, the first hole **141** and the second hole **142** are respectively provided such that positions in the radial direction of the cylinder **11** are near the seal part **15** where the electrically-conductive paint tends to remain. Thereby, since the cleaning fluid W can be supplied near the seal part **15**, cleaning efficiency improves.

As shown in FIG. **9** and FIG. **10**, in the intermediate storage device **10** having the above structure, the extreme end surface **12***a* (**172***a*) of the piston **12** slides until near the extreme end **110** of the cylinder **11** at the time of cleaning. Thereby, the cylinder chamber **14** is formed in a very small space between the extreme end surface **12***a* (**172***a*) of the piston **12** and the extreme end **110** of the cylinder **11**. The electrically-conductive paint remains in the cylinder chamber **14** having small volume and the remained electrically-conductive paint is removed by being cleaned by the cleaning fluid W at the time of cleaning.

Hereafter, with reference to FIG. **9**, operation of the electrostatic coating device **1** at the time of cleaning the low viscosity paint when the pressure in the cylinder chamber **14** is lower than the supply pressure of the fluid F supplied into the cylinder chamber **14** will be described. In addition, with reference to FIG. **10**, operation of the electrostatic coating device **1** at the time of cleaning the high viscosity paint when the pressure in the cylinder chamber **14** is higher than the supply pressure of the fluid F supplied into the cylinder chamber **14** will be described.

It should be noted that, in the present embodiment, the supply pressure of the fluid F is set to predetermined fixed supply pressure by the control device **70** at the time of cleaning. In addition, at the time of cleaning, cleaning is performed by the control device **70** in a state where the piston **12** is stopped, more specifically, in a state where the piston body **120** is stopped.

First, when the viscosity of the paint is low, there is a good flow of the cleaning fluid W which flows through inside the cylinder chamber **14** and the route pressure is low. Therefore, since the pressure in the cylinder chamber **14** is lower than the supply pressure of the fluid F, the displacing part **172** is not displaced and the position of the extreme end surface **12***a* (**172***a*) of the piston **12** is not displaced with respect to the piston body **120** and the cylinder **11** as shown in FIG. **9**. Thereby, a state where the gap C**1** between the extreme end surface **12***a* (**172***a*) of the piston **12** and the extreme end **110** of the cylinder **11** is small is maintained, and as a result, a state where the volume of the cylinder chamber **14** is small is maintained.

Here, FIG. **11** is a diagram showing the relation between the pressure in the cylinder chamber **14** and the position of the extreme end surface **12***a* (**172***a*) of the piston **12** at the time of cleaning the low viscosity paint. As shown in FIG. **11**, at the time of cleaning the low viscosity paint, although the pressure in the cylinder chamber **14** increases when the cleaning starts, the pressure in the cylinder chamber **14** does not exceed the supply pressure of the fluid F at all. Therefore, the displacing part **172** is not displaced and the position of the extreme end surface **12***a* (**172***a*) of the piston **12** is not displaced with respect to the cylinder **11** and the piston body **120** and thus locates at the original position.

In contrast, when the viscosity of the paint is high, there is only a poor flow of the cleaning fluid W which flows through inside the cylinder chamber **14** and the route pressure is high.

Therefore, since the pressure in the cylinder chamber **14** is higher than the supply pressure of the fluid F, the displacing part **172** is displaced and the position of the extreme end surface **12***a* (**172***a*) of the piston **12** is displaced with respect to the cylinder **11** and the piston body **120** as shown in FIG. **10**. Specifically, the position of the extreme end surface **12***a* (**172***a*) of the piston **12** is displaced with respect to the cylinder **11** and the piston body **120** to the base end side (upper side in FIG. **10**). Thereby, the gap C2 between the extreme end surface **12***a* (**172***a*) of the piston **12** and the extreme end **110** of the cylinder **11** becomes larger than C1 shown in FIG. **9**, and as a result, the volume of the cylinder chamber **14** becomes larger.

Here, FIG. **12** is a diagram showing the relation between the pressure in the cylinder chamber **14** and the position of the extreme end surface **12***a* (**172***a*) of the piston **12** at the time of cleaning the high viscosity paint. As shown in FIG. **12**, at the time of cleaning the high viscosity paint, the pressure in the cylinder chamber **14** increases when the cleaning starts and the pressure in the cylinder chamber **14** exceeds the supply pressure of the fluid F. Therefore, the displacing part **172** is displaced and the position of the extreme end surface **12***a* (**172***a*) of the piston **12** is displaced with respect to the piston body **120** and the cylinder **11** to the base end side.

In addition, since the amount of the cleaning fluid W increases with respect to the electrically-conductive paint remaining in the cylinder chamber **14** and the viscosity of the remaining electrically-conductive paint is lowered when the position of the extreme end surface **12***a* (**172***a*) of the piston **12** is displaced to the base end side, cleaning is promoted and cleaning efficiency improves. As shown in FIG. **12**, since the pressure in the cylinder chamber **14** decreases and the pressure in the cylinder chamber **14** becomes lower than the supply pressure of the fluid F as the cleaning goes on, the displacing part **172** returns to the original position gradually. Thereby, the position of the extreme end surface **12***a* (**172***a*) of the piston **12** returns to the original position also. That is, the size of the gap C2 between the extreme end surface **12***a* (**172***a*) of the piston **12** and the extreme end **110** of the cylinder **11** returns to the size of C1 and the volume of the cylinder chamber **14** becomes in its original small state shown in FIG. **9**.

Next, operation of the electrostatic coating device **1** at the time of coating will be described.

First, the first dumping valve **31**, the second dumping valve **41** and the second trigger valve **42** are closed and one of the paint valves and the first trigger valve **32** are opened by the control device **70**. In addition, the servo-motor **13** of the intermediate storage device **10** is driven by the control device **70**. Thereby, the electrically-conductive paint of predetermined coating color is pressure-fed into the cylinder chamber **14** of the intermediate storage device **10** and the electrically-conductive paint is supplied to the second trigger valve **42**.

Next, after completing filling of the electrically-conductive paint into the cylinder chamber **14**, the voltage block mechanism (not illustrated) is controlled by the control device **70** to electrically insulate the color switching valve mechanism **20** and the intermediate storage device **10**.

Next, with the control device **70**, the second trigger valve **42** is opened and the piston **12** is advanced with respect to the cylinder **11** by the drive action of the servo-motor **13**. Then, the electrically-conductive paint stored in the cylinder chamber **14** is pressure-fed towards the coating gun **60**. The electrically-conductive paint pressure-fed by the coating gun **60** is applied with high voltage in the high voltage application unit and is discharged from the extreme end of the coating gun **60** in this state. Thereby, electrostatic coating of the electrically-conductive paint is carried out with respect to the object to be coated.

Here, at the time of paint discharge, the fluid supply source is controlled by the control device **70** such that the supply pressure of the fluid F is always higher than the pressure in the cylinder chamber **14**. Thereby, the position of the extreme end surface **12***a* (**172***a*) of the piston **12** is controlled such that it is not displaced and the amount of supply to the coating gun **60** is controlled accurately.

It should be noted that since impact is absorbed by the displacement mechanism **17** even when the extreme end of the piston **12** collides with the inner wall of the cylinder **11** or the like as a result of abnormalities or positional disagreement when advancing the piston **12** with respect to the cylinder **11**, the affect of the piston body **120** and the servo-motor **13** is reduced.

After electrostatic coating is completed, the second trigger valve **42** is closed and the application of high voltage to the coating gun **60** is canceled. In addition, electric insulation between the color switching valve mechanism **20** and the intermediate storage device **10** by the voltage block mechanism is canceled.

Next, with the control device **70**, the first cleaning valve **21**, the first trigger valve **32** and the second dumping valve **41** are opened and the first dumping valve **31** and the second cleaning valve **51** are closed. Thereby, the cylinder chamber **14** is cleaned by supplying the cleaning fluid W from the first hole **141** and discharging from the second hole **142** the waste fluid that has undergone cleaning. In addition, in the present embodiment, in order to improve the cleaning efficiency of the cylinder chamber **14** as that of the first embodiment, the cylinder chamber **14** can be cleaned by switching with a switching unit of the control device **70** between a first cleaning which is performed by a first cleaning unit and supplies the cleaning fluid W from the first hole **141** and a second cleaning which is performed by a second cleaning unit and supplies the cleaning fluid W from the second hole **142**. It should be noted that the first cleaning may be further performed after the second cleaning, and the first cleaning and the second cleaning may be repeated alternately.

Thus, electrostatic coating is performed by newly supplying electrically-conductive paint of different coating color in the same procedure as the above-described procedure after cleaning the cylinder chamber **14**.

The present embodiment exerts the following advantageous effects.

In the present embodiment, there is provided a displacement mechanism **17** which displaces the position of the extreme end surface **12***a* (**172***a*) of the piston **12** with respect to the cylinder **11** by displacing the position of the extreme end surface **12***a* (**172***a*) of the piston **12** with respect to the piston body **120** when the pressure in the cylinder chamber **14** exceeds predetermined pressure, more specifically, predetermined fixed supply pressure of the fluid F, by filling the cleaning fluid W into the cylinder chamber **14**.

According to the present embodiment, the electrically-conductive paint remaining in the cylinder chamber **14** at the time of cleaning serves as resistance to the flow of the cleaning fluid W causing the pressure in the cylinder chamber **14** to increase and exceed predetermined fixed supply pressure of the fluid F and the position of the extreme end surface **12***a* (**172***a*) of the piston **12** with respect to the piston body **120** is displaced automatically without being controlled. Thereby, the position of the extreme end surface **12***a* (**172***a*) of the piston **12** with respect to the cylinder **11** is displaced. Accordingly, since the volume in the cylinder chamber **14** increases and the amount of the cleaning fluid W with respect to the electrically-conductive paint remaining in the cylinder chamber **14** increases causing the viscosity of the electrically-conductive paint to be lowered, cleaning efficiency can be improved. Therefore, according to the present embodiment, it is possible to clean inside the cylinder chamber **14** effectively irrespective of the type of electrically-conductive paint.

In addition, the present embodiment controls such that the position of the extreme end surface **12***a* of the piston **12** with respect to the piston body **120** is not displaced during the coating, that is, when extruding the electrically-conductive paint filled inside the cylinder chamber **14**.

According to the present embodiment, since the position of the extreme end surface **12***a* (**172***a*) of the piston **12** with respect to the piston body **120** is not displaced during the coating, it is possible to supply an accurate amount of electrically-conductive paint to the coating gun **60**.

In addition, according to the method for coating that uses the electrostatic coating device **1** in the present embodiment, it is possible to clean the cylinder chamber **14** efficiently irrespective of the type of electrically-conductive paint by filling the cleaning fluid W in the cylinder chamber **14** at the time of cleaning and displacing the position of the extreme end surface **12***a* (**172***a*) of the piston **12** with respect to the cylinder **11**.

Sixth Embodiment

The electrostatic coating device according to the sixth embodiment has the same structure as the fifth embodiment except that the structure of the displacement mechanism is different from that of the fifth embodiment.

FIG. **13** is an enlarged cross-sectional view of the intermediate storage device **90** of the electrostatic coating device according to the second embodiment. As shown in FIG. **13**, in contrast to the fluid supply source of the fluid F of the fifth embodiment, the driving source of the displacement mechanism **97** included in the intermediate storage device **90** includes an elastic body **19** having, for example, a plurality of compression springs. Therefore, the fluid supply path is not formed inside the piston body **920**.

A plurality of elastic bodies **19** are provided in an elastic room **97***a* which is larger than the fluid room **17***a* in the fifth embodiment. The elastic room **97***a* is formed between a concave portion **922** formed depressed to the base end side on the extreme end surface of the piston body **920** and a base end flange part **172***d* of the displacing part **172**.

A plurality of elastic bodies **19** pushes the displacing part **172** to the extreme end side in an initial state which is before coating. Thereby, as shown in FIG. **13**, in the initial state before coating, the extreme end surface of the base end flange part **172***d* contacts with the base end surface of the cylinder small diameter part **171***a* and the displacing part **172** is arranged at the most extreme end side.

In addition, in the present embodiment, at the time of cleaning, the displacing part **172** is displaced automatically without being controlled when the cleaning fluid W is filled in the cylinder chamber **14** and the pressure in the cylinder chamber **14** exceeds the pushing force. Specifically, the position of the extreme end surface **92***a* of the piston **92** with respect to the cylinder **11** can be automatically displaced to the base end side by displacing the position of the extreme end surface **92***a* of the piston **92** with respect to the piston body **920** automatically to the base end side.

In addition, when the position of the extreme end surface **92***a* of the piston **92** is displaced to the base end side, the amount of the cleaning fluid W with respect to the electrically-conductive paint remaining in the cylinder chamber **14** increases and the viscosity of the remained electrically-conductive paint is lowered and thus cleaning is promoted and cleaning efficiency improves. As the cleaning progresses, the pressure in the cylinder chamber **14** decreases and the pressure in the cylinder chamber **14** becomes lower than the pushing force of the plurality of elastic bodies **19**, and thus the displacing part **172** returns to the original position gradually and the position of the extreme end surface **92***a* of the piston **92** returns to the original position.

Therefore, the present embodiment exerts the same advantageous effects as the fifth embodiment at the time of cleaning with a structure simpler than the fifth embodiment.

The present invention is not limited to the above-described embodiments and the present invention includes modifications, improvements and the like within the range that can accomplish the object of the present invention.

For example, although fluid F is used as a driving source of the displacement mechanism in the fifth embodiment and a plurality of elastic bodies are used as a driving source of the displacement mechanism in the sixth embodiment, the present invention is not limited thereto. Instead of the fluid F or the elastic bodies, a motor can be used as a driving source of the displacement mechanism. When using the motor as a driving source of the displacement mechanism, a pressure detection means which detects the pressure in the cylinder chamber may be provided to control the rotation speed of the motor by the control device based on the detected values.

Specifically, the rotation speed of the motor may be controlled such that, at the time of cleaning, the control device suppresses the rotation speed when the detected pressure in the detected cylinder chamber reaches predetermined pressure, and at the time of coating, the position of the extreme end surface of the piston with respect to the cylinder is not displaced according to the detected pressure in the cylinder chamber.

What is claimed is:

1. An intermediate storage device of an electrostatic coating system, comprising:

- a cylinder which is provided between a paint supply source and a coating gun and stores paint;
- a piston which can slide inside a cylinder chamber of the cylinder, wherein the cylinder chamber is formed inside the cylinder; and
- a driving source which drives the piston, the intermediate storage device further comprises:
- a first hole which is open to the cylinder chamber and is connected to the paint supply source;
- a second hole which is open to the cylinder chamber and is connected to the coating gun, wherein the first hole and the second hole are arranged on mutually opposite sides of a circumference of the cylinder, and an opening diameter of the first hole and an opening diameter of the second hole are different so as to improve cleaning efficiency of the cylinder chamber;
- a first cleaning device having a first cleaning valve for controlling a supply of a cleaning fluid and drying air by a flow in a first direction toward the first hole so as to clean the cylinder chamber by supplying the cleaning fluid from the first hole and discharging from the second hole waste fluid that has undergone cleaning;
- a second cleaning device having a second cleaning valve for controlling the supply of the cleaning fluid and the drying air by a flow in a second direction toward the second hole so as to clean the cylinder chamber by supplying the cleaning fluid from the second hole and discharging from the first hole waste fluid that has undergone cleaning; and

a switch device that switches between cleaning performed by the first cleaning device and cleaning performed by the second cleaning device.

2. The intermediate storage device of an electrostatic coating system according to claim **1**, further comprising

an annular seal member which fits into an outer peripheral of an extreme end of the piston, wherein

an extreme end surface of the seal member opposing an extreme end of the cylinder is formed substantially in-plane with an extreme end surface of the piston, whereby a length of the cylinder chamber in a direction of the cylinder axis can be made substantially uniform while securing the flow of the cleaning fluid.

3. The intermediate storage device of an electrostatic coating system according to claim **1**, further comprising

a driving source controller that drives the piston by controlling the driving source during cleaning performed by the first cleaning device and cleaning performed by the second cleaning device.

4. The intermediate storage device of an electrostatic coating system according to claim **1**, further comprising

a displacement mechanism including an inner cylinder part fixed onto an extreme end surface of a body of the piston and a displacing part, an end portion of which forms the extreme end surface of the piston, to be capable of displacing relative to the inner cylinder part, and wherein the displacement mechanism displaces a position of the extreme end surface of the piston with respect to the cylinder by displacing the position of the extreme end surface of the piston with respect to the body of the piston.

5. The intermediate storage device of an electrostatic coating system according to claim **4**, further comprising

a controller that controls the displacement mechanism such that the position of the extreme end surface of the piston with respect to the body of the piston is not displaced during coating, whereby an amount of supply to the coating gun is controlled accurately.

6. The intermediate storage device of an electrostatic coating system according to claim **2**, further comprising

a driving source controller that drives the piston by controlling the driving source during cleaning performed by the first cleaning device and cleaning performed by the second cleaning device.

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